Protocol for boat electrofishing in nearshore areas of the lower Great Lakes: transect and point survey methods for collecting fish and habitat data, 1988 to 2002.

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ABSTRACT

Brousseau, C.M., Randall, R.G., and Clark, M.G. 2005. Protocol for boat electrofishing in nearshore areas of the lower Great Lakes: transect and point survey methods for collecting fish and habitat data, 1988 to 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2702

Standardized protocols were used to survey fish and habitat in nearshore areas of the lower Great Lakes since 1988. The objectives were to evaluate the status of the fish communities in Great Lakes' Areas of Concern (regions with degraded water quality and habitat), and to evaluate the productive capacity of nearshore habitat at natural and altered shorelines. This report provides details of the fish and habitat surveys protocol that were used. Fish were captured by boat electrofishing at 100 m line transects, and in recent years, by point sampling. In both cases, survey locations were stratified and replicated in habitats with different substrate, cover and shoreline characteristics. Line and point sample protocols provided data at different spatial scales, but both were conducted in a consistent manner to allow the analysis of temporal and spatial trends in fish catches and their associated habitats. Fish and habitat information were recorded on field sheets, and later transferred to a computer database. The nearshore database has been used for both research and management purposes, demonstrating the advantages of using standard survey protocols in the Great Lakes.

RÉSUMÉ

Brousseau, C.M., Randall, R.G., and Clark, M.G. 2005. Protocole de pêche électrique par bateau dans les régions littorales des Grands lacs inférieurs : méthode de relevée par transect linéaire et par échantillonnage ponctuel pour la collecte des données de poissons et de leurs habitats, de 1988 à 2002.

Des relevés du poisson et de l'habitat sont effectués selon des protocoles normalisés dans les régions littorales des Grands Lacs inférieurs depuis 1988. Les relevés visent à évaluer l'état des communautés de poissons dans les secteurs préoccupants des Grands Lacs (secteurs dont la qualité de l'eau et l'habitat sont dégradés) et à déterminer la capacité de production de l'habitat littoral dans des secteurs aux rives naturelles ou modifiées. Ce rapport présente les détails du protocole de relevé utilisé. Les poissons ont été capturés par pêche électrique au moyen d'un bateau sur des transects linéaires de 100 m, et, ces dernières années, par échantillonnage ponctuel. Dans les deux cas, l'échantillonnage était stratifié et répété dans des habitats dont le substrat, le couvert végétal et les caractéristiques des rives différaient. Les échantillonnages linéaire et ponctuel ont fourni des données à différentes échelles spatiales, mais ils ont tous les deux été effectués d'une façon uniforme afin de permettre l'analyse des tendances temporelles et spatiales des captures de poissons et de leurs habitats. Les données sur les poissons et les habitats ont été consignées sur des fiches de terrain, puis entrées dans une base de données informatique. Cette base de données a servi à des fins de recherche et de gestion et a mis en évidence les avantages de l'utilisation de protocoles de relevé normalisés dans les Grands Lacs.

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INTRODUCTION

The goal of this report is to describe two protocols for surveying fish and habitat using an electrofishing boat and a line or point survey method in littoral habitats of the lower Great Lakes. The two survey methods were used by the Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS), Fisheries and Oceans Canada (DFO) at Burlington for various projects that deal with nearshore fish assemblages and the productive capacity of shoreline fish habitat. The line and point survey protocols facilitated the collection of data in an organized, consistent manner, which increases the usefulness of the data over the long term (Stanfield et al. 1999; Bonar and Hubert 2002). To date, approximately 90% of the data collection has used the line survey protocol. Point sampling was initiated in more recent years (2000 to 2002) to investigate fish habitat linkages and to compare effort and sampling efficiency between the two methods.

Nearshore electrofishing surveys were started in the Great Lakes' by DFO in 1988. Initially, the goal was to collect fish and habitat data from Great Lakes' Areas of Concern in Lake Ontario (Hamilton Harbour and Bay of Quinte) and Severn Sound, Georgian Bay. Areas of Concern (AOC) were regions with degraded water quality and habitat that resulted in impaired beneficial uses (Hartig et al. 1997; EPA 2002). Since 1988, the survey locations have been expanded to include non-AOC shorelines in Lake Erie and Lake Ontario, to provide information on spatial variability in habitat productive capacity. Data from the nearshore surveys have been used for evaluating the effects of habitat change at AOCs (Smokorowski et al. 1998; Boston and Randall 2001), for determining linkages between physical habitat and fish abundance (Randall et al. 1993; Kelso and Minns 1996; MacLeod et al. 1995; Randall et al. 1996; Minns et al. 1993; Minns et al. 1995; Randall et al. 1998; Randall et al. 1999), for determining biological indices of productive capacity (Minns et al. 1993; Randall and Minns 2002), for validating a Defensible Methods approach (Minns et al. 1995; Minns 1997) for evaluating habitat supply and conservation (Minns et al. 1996; Minns et al. 2001), and for developing regional Fish Habitat Management Plans (Minns et al. 1999). From 1988 to 2002, all surveys were conducted using a standardized line transect (100 metres) protocol. An earlier description of the transect survey protocol was provided by Valere (1996). Beginning in 2000, a point sampling protocol was also designed and tested as an alternative method for surveying fish and habitat with a higher spatial resolution than the

transect protocol. All field data from both transect and point sampling were entered into a computer database (Moore et al. 1998). The purpose of this report is to update the transect protocol description, and to provide details of the new point sample protocol. The protocol descriptions will be useful to researchers who use the existing database in future, and hopefully to others who decide to adopt the protocol for surveying littoral habitat in the Great Lakes and elsewhere.

This report is comprised of eight sections: 1) introduction; 2) Great Lakes littoral habitat; 3) current database; 4) pre-survey set-up; 5) fish measurements; 6) habitat measurements; 7) database description; 8) relevance of habitat and environmental measurements, 9) acknowledgements, and 10) references. Specific measurements for point and line transect protocols are given separately in sections 5) and 6). Field data forms are provided as tables, and the specifics of the data entries are provided in detail in Appendices 1 to 3. A safety checklist for electrofishing is provided in Appendix 4. A listing of sampling stations and associated habitat information is found in Appendix 5. Maps of all study areas are provided.

GREAT LAKES' LITTORAL HABITAT

To provide a context and background for the application of the protocols, the characteristics of the physical habitat where the surveys have been conducted in the lower Great Lakes are summarized briefly in this section.

The lower Laurentian Great Lakes are large (Lake Ontario - 19,100 km^2; Lake Erie - 25,700 km^2, and Georgian Bay - 15,500 km^2), and wind exposure (fetch) is a dominant influence for much of the nearshore area, affecting water currents, substrate and the occurrence of aquatic plants. In sheltered embayments, where most of the fish studies have occurred, surveying was challenging because of the diversity of aquatic habitats and the range in wind-exposure conditions that existed. Habitat types ranged from the natural igneous shorelines of the Canadian Shield in upper Georgian Bay to the sedimentary shorelines of Lake Erie and Lake Ontario that have been altered in urban areas (harbours, docks, piers and hardened shorelines). Surveys have been successfully conducted in habitats ranging from protected coastal wetlands with abundant vegetation (Presqu'ile, inner Long Point) to extremely exposed shorelines adjacent to harbours with wave-washed sand or coarse substrates (Port Dover, Bronte Harbour).

Nearshore data were collected from 24 areas of the lower Lakes (Table 1, Figures 3-27). Water quality and physical habitat differed among these areas (Table 2). Water conductivity varied among the survey areas, ranging from 210 to 540 μS/cm at Severn Sound and Hamilton Harbour, respectively. Water turbidity, as measured by secchi depth, varied among the study locations from < 0.1 to > 5 m, but usually ranged between 1.5 and 3.5 at most study areas. Average surface water temperatures at the time of the survey ranged between 14.5°C and 22.5°C. All of these water quality characteristics influenced fish distribution and electrofishing operations.

Macrophyte density and substrate type were also important habitat variables that influenced fish catches. Land use, substrate type, water depth, turbidity, and nutrient levels all influenced macrophyte distribution. Macrophyte presence and abundance was documented in most study areas. Submerged macrophytes were abundant at certain locations (e.g., Matchedash, Long Point, Presqu'ile, and Trenton) and were sparse at others (Table 2). Macrophyte occurrence and density was spatially and temporally dynamic. Macrophytes increased in recent years at some locations (e.g., Bay of Quinte;

Seifried 2001) due to improved water clarity, possibly because of the increase in abundance of *Dreissena sp.* (zebra mussels). Changes in macrophyte abundance were correlated with fish community change (e.g., an increase in centrarchids) in the Bay of Quinte (Boston and Randall 2001).

Substrate type among the study areas varied from organic-rich mud to bedrock. Fetch, water current, fluvial inputs, altered shorelines and urbanization influenced areas of sediment deposition and erosion. Surveys were conducted in areas with natural substrate ranging from silt to cobble or bedrock and in areas with artificial infill (breakwalls). Additional substrate and macrophyte information for individual transect locations is documented in Appendix 5.

Fish species richness in the nearshore areas of the lower Great Lakes was relatively high (Table 4a). For example, 30 to 34 species of fish were captured by transect electrofishing at several areas in the Bay of Quinte and Prince Edward County, eastern Lake Ontario (Table 4a). In contrast, richness in inland lakes in Ontario is often less than 10 species (Minns 1989). The average fish density per transect varied by area: Severn Sound (36.80), Lake Erie (19.27), western Lake Ontario (52.90), and eastern Lake Ontario (54.03) (Table 3). The average biomass (kg) per transect also varied between areas: Severn Sound (3.49 kg), Lake Erie (2.99 kg), western Lake Ontario (8.13 kg), and eastern Lake Ontario (3.59 kg) (Table 3). Habitat, season, and time period were all examples of variables that affected the fish catch in an area.

With high species richness and a diversity of habitats, electrofishing has proven to be an effective sampling method in littoral areas of the Great Lakes. Fish can be captured at most habitat areas, and most species were vulnerable to capture. Other types of passive (gill and fyke nets) and active (seining, trawling) capture methods have been used in littoral areas, but all were species or size selective, and their effectiveness depended on habitat conditions (Hubert 1996; Hayes et al. 1996). Although effective, boat electrofishing in the Great Lakes by DFO has been limited to areas 2 m in depth or less, and surveys at exposed shoreline areas have been limited to areas adjacent to harbours for logistical and safety reasons.

CURRENT DATABASE

The database (1988-2002) currently includes 78,921 individual fish records from 24 areas in the lower Great Lakes (Table 1). About 2,434 samples were collected at 354 different transects (i.e., many transects were surveyed on several different dates). In addition, about 1,858 point samples were collected. All point samples to date have been collected in the vicinity of existing transect locations.

PRE-SURVEY TASKS

A scientist or manager will determine the number of transects or points to be sampled within a target study area based on the objectives of the study and a pre-determined study design. Site determination is often hierarchical, starting with an area of interest (bay) and then focusing on particular habitat types within the area. Site (transect or point) determination can be random, stratified random (based on habitat strata), or fixed sites based on *a priori* criteria. In all cases, prior knowledge of the habitat to be surveyed (water depth, substrate, cover, exposure and accessibility) was needed.

The selection of an electrofishing protocol will depend on the objectives of a survey. Although transects were often chosen in areas of relatively uniform habitat, several habitat boundaries (e.g., substrate, % cover) can be crossed within the 100 m distance. Point sampling provided higher spatial resolution than transect sampling, allowing a comparison of the fish catch data to specific habitat variables. Because of the smaller area, fewer fish were captured in individual point samples than transect samples, but a larger number of point samples were obtained over transect samples in one survey day (Table 5a) and less effort was required to obtain a coefficient of variation of the mean of 0.20 using the point sampling protocol (Table 5b).

Differential GPS readings should be taken at transects or points to aid in the relocation of sites on repeat visits, and to provide a permanent position record for future reference. When feasible, the 100 m transect boundaries were marked on shore prior to the beginning of a survey. Shore markers such as reflectors and/or spray paint can be put on trees or preferably large boulders. Reflectors were preferred as they make start and end points more visible at night. In urban areas, small reflectors can be attached to docks with an owner's permission and permanent landmarks must be well documented

(e.g., docks, boathouses, flagpoles, sheds). It was necessary to record as much information about transects as possible because over time, changes occur that can make transect relocation difficult. Bearings and distances to shore were also used to identify transect markers.

FIELD CREW

A typical boat electrofishing crew consisted of four people who have been trained in electrofishing procedures and standards, boat and trailering safety, first aid and cardiopulmonary resuscitation (CPR). In Ontario, electrofishing training was provided by the Ontario Ministry of Natural Resources (OMNR) (Straszynski et al. 2001) and certified electrofishing crew leaders. A boat electrofishing crew must have at least one certified crew leader who is in charge of the survey operation. Other crew members must also be trained according to OMNR guidelines. To be classified as a crew leader, the OMNR stipulates that a person must complete the OMNR electrofishing training course and have current CPR training; the electrofishing training must be updated every 5 years (Straszynski et al. 2001). To be classified as a crew member, staff must complete a one-day training course designed specifically for electrofishing boats given by a certified crew leader. All crew members must also possess a valid CPR certificate.

During an electrofishing boat operation, the crew leader was stationed at the console and was responsible for driving the boat and operation of electrofishing components. Two crew members were positioned on the bow of the boat and were responsible for netting the shocked fish and transferring them to the live-well using dip nets with long (3 m) fibreglass or wooden handles. The fourth crew member was stationed at the live-well and assisted the netters with emptying their nets into the live-well. For safety, each crew member had a "dead man" foot-petal, connected in series. All pedals must be depressed to complete the circuit and to provide a current output. All crew members followed the safety guidelines listed for boat electrofishing (Appendix 4).

A crew of four people was usually needed for boat electrofishing at line transects. It is possible to conduct a survey with a crew of three, but catch efficiency may not be as high, as emptying the nets at the live-well was more time-consuming, leaving less time for netting fish at the bow. A three-person crew was suitable for point sampling, as the electrofishing duration was shorter (10 seconds) and netters had time to empty their nets into the appropriate buckets after the current was shut off.

BOAT SPECIFICATIONS AND CONFIGURATION

Transect: Transect electrofishing was carried out using a Smith-Root SR20E electrofishing boat (length=6.1 m, beam=1.9m) (Smith 1984). A 16 hp gas motor driving a 7.5 kW generator produced the electric current. Since 1992, electrical output has been standardized at about 8 amperes (A). The electrode configuration consisted of two anodes, each with a terminal six wire umbrella array, extended out from the bow at approximately 25°, with the aluminum boat acting as the cathode (Novotny and Priegel 1974).

Annual servicing of the outboard and the gasoline engine for generator, and periodic servicing of generator and electrical circuits were needed. Annual and daily safety checklists for boat electrofishing are provided in Appendix 4.

Point: A Smith-Root electrofishing boat was also used for point sampling (Smith 1984). The electrode configuration consisted of a singe anode (terminal six-wire umbrella array) off the centre bow of the stationary boat. Output was standardized to 8.0 A when possible. At shallow depths (0.5 m and 1.0 m), the maximum output ranged from 6.0 to 8.0 A.

WEATHER

Weather conditions will determine if sampling can occur on a specific date. Electrofishing or habitat sampling will not take place if lighting storms or rain are present in an area. High winds and waves can also pose problems; the boat can not stay in place or maintain a constant survey speed and there is the danger of being blown onto shore. Weather information can be obtained from the local Coast Guard marine forecast (VHF radio), Environment Canada (internet, phone) and The Weather Network (internet, television).

Light rain may be tolerable when gathering habitat data, as long as the crew is comfortable and electrical storms are not present in the area. Wind can still be a problem because of the close proximity to shore, and the need to hold the boat in a stationary position to take measurements. In addition, macrophytes might not be visible if the water has become turbid due to wave action or if raindrops have disrupted the surface.

FISH SURVEY PROTOCOL AND MEASUREMENTS

TRANSECTS

Electrofishing was conducted at the 1.5 m depth contour along 100 m transects (Figure 1). Transects were surveyed at idle speed using a 90 hp to 150 hp outboard motor (about 0.3 m per second) resulting in a sampling duration of about 5 minutes (range 3-6 minutes) to complete the transect. Electrofishing commenced one to two hours before sunset and extended into the late evening (23:00 to 01:00 h). Wind speed and macrophyte density affected the time that it took to sample transects. After a transect was completed, measures of wind speed and direction (meteorological reports), shocking duration (seconds), voltage, amperage output, and percent of voltage range were recorded from the boat gauges (Table 6 and Appendix 1). Once netted, the fish were held in an aerated live-well with two holding tanks.

Two transects were sampled before stopping to process the fish. Fish were identified to species (Scott and Crossman 1973, Mandrak and Crossman 1992), and lengths and weights were obtained. Fish were measured to fork length (± 1 mm). Fish that had a rounded or caudal fin were measured at total length (Valere 1996). Different models of Sartorius digital balances (Basic^{lite} Series) were used to weigh small fish up to 300 grams (model BL150), and larger fish up to 6000 grams (model BL6). Fish that were greater than 6 kg or that were too long to fit on a digital balance (e.g., northern pike) were placed in a mesh sling (of pre-determined weight) and weighed with a Chatillon (Model 25) hanging spring scale to the nearest 100 grams (with a capacity of 12,500 grams). Fish were weighed and measured individually up to a maximum of 20 fish per species at each transect. When catches of a particular species exceeded 20 fish, the fish were counted and batch weighed. Fish that cannot be identified in the field were measured, weighed, sacrificed and kept for identification at a later date. Unknown fish were identified, using the keys in Scott and Crossman (1973). Beginning in 2002, voucher specimens were collected to verify identifications; one specimen per species at each survey area was kept. All data elements on the fish field data sheet (Table 6) are described in detail in Appendix 1.

POINTS

All point samples identified within the shore boundaries of a 100 metre transect were electrofished (Figure 2). Each point sample was approached slowly by the

electrofishing boat. Electrofishing commenced when a crew member at the bow signalled (raises arm) to the boat driver that the anode was positioned directly over a point-float. The boat was held stationary while the point sample was fished for 10 continuous seconds. The crew member that operated the live-well initiated the power output by stepping on his/her foot petal, counting for 10 seconds and then removing his or her foot from the pedal to terminate sampling.

After a point was electrofished, captured fish were placed in 1 of 10 individual buckets in the live-well of the boat. Then, the float was removed from the water and placed in the corresponding bucket of fish. Floats that did not have fish catches associated with them were put aside and the point sample was recorded as a null catch. When each of the 10 buckets on the boat held a fish sample, the crew processed the fish before proceeding. Once all point samples within a transect location were fished, measures of wind speed and direction, shocking seconds, voltage, amperage output, and percent of range (voltage) were recorded (Table 6 and Appendix 1). Like line surveys, wind and wave conditions had to be optimal in order to sample. The stop time recorded was the time it took to fish and process all point samples from one area.

The protocol for processing fish was the same as that for transects. For fish captured point sampling, the corresponding sample location (marker number and depth) was also recorded on the data sheet (Table 6).

All data elements on the fish sampling data sheet are described in further detail in Appendix 1.

HABITAT SURVEY PROTOCOL AND MEASUREMENTS

LINE TRANSECT

Habitat sampling was conducted at the1.5 m depth contour (approximately), along 100 metre transects. Habitat measurements included substrate, cover, water temperature, water conductivity, dissolved oxygen and location (GPS). Shore markers (i.e. reflectors, paint on rocks and trees) and GPS positions identified the beginning and end of a transect (Table 7). In areas where shore markers couldn't be established, visual descriptions of permanent features (e.g. docks, telephone poles) were recorded in addition to GPS geo-referencing. Prior to sampling, floats were laid out at the 1.5 m depth contour to visually mark the start and end of a transect (Figure 1). Habitat measurements were recorded prior to sunset and usually before electrofishing.

Specific habitat measurements were taken at three locations along a transect: start, middle, and end (Figure 1) and were recorded on a transect habitat data sheet (Table 7). At the start of each transect, measurements of location and substrate compositions were recorded. Coordinates of longitude and latitude were obtained from differential GPS positions (NAD83) using a Garmin GPSMAP 175 (within 10 meters 95% of the time). Laser range finders (± 1.0 m) were used to record the distance from the float marker to shore (Figure 1) and the orientation of the marker (north, south, east or west) related to the shoreline was recorded (Table 7).

Measures of dissolved oxygen, conductivity, water temperature and secchi depth were taken at the middle of each transect and at a point on the 5.0 m depth contour offshore and perpendicular to the transect (Figure 1). Dissolved oxygen (mg/L), conductivity (µS/cm) and water temperature (°C) were taken with a YSI (model 85) instrument. The accuracy of the YSI is as follows: for conductivity ± 0.5% µmhos, temperature ± 0.1°C and dissolved oxygen ± 0.3 mg/L. Secchi depth readings were taken using a standard secchi disk (20 cm in diameter). The disc was lowered into the water on the shady side of the boat until it disappeared from view, and was then raised until it reappeared. The average of the disappearance and reappearance depths was recorded as the secchi depth (i.e. transparency). When the lake bottom was visible, secchi depth was recorded as greater than 1.5 metres.

Substrate was sampled at each transect marker either visually or for finer substrates, with a scissor-handled grab that pulls up a sample of substrate much like an Ekman sampler (which can also be used). The substrate was visually (sometimes

texturally) classified by six classes of substrate size: silt (0.0039 mm to 0.0625 mm), sand (0.0625 mm to 2 mm), gravel (2 mm to 16 mm), pebble (16 mm to 64 mm), cobble (64 mm to 256 mm) and boulder (>256 mm). Other substrate classes included flat bedrock, organic debris, woody debris and zebra mussels. Dominant (>50 %), sub-dominant (10 to 50 %) and trace (<10 %) components of substrate were recorded on the field sheets (Table 7).

Macrophyte abundance at transects was estimated using two methods: visual estimation and echo sounding. Visually, macrophyte abundance was assigned to one of four categories: none (0 %), sparse (1 to 19 %), moderate (20 to 70 %) or dense (>70 %). Dominant macrophytes were identified to genus and recorded on the field sheet (Fassett 1966; Hotchkiss 1967) (Table 7). If a plant could not be identified in the field, a sample was taken in a plastic bag and kept moist for identification at a later time. Echosounding was conducted with a Lowrance X16 paper graph recorder. Settings were specific for different bottom types and predetermined to optimize the length, resolution, depth range and readability of the echogram (Table 8). An echogram was taken along the 100 metre transect at the 1.5 m depth parallel to shore (Figure 12). Boat speed was kept constant by starting the boat far enough ahead of the start point that idle speed was achieved before recording starts.

All fields on the transect habitat data sheet (Table 7) are described in detail in Appendix 2.

POINT SAMPLES

Point samples were laid out in random locations within the boundaries of defined line transects (Figure 2). Points were established at four different depths: 0.5 m, 1.0 m, 1.5 m and 2.0 m. Within each transect up to five random markers were positioned at each of the four depths (Figure 2). Points were established at least 2 metres apart so that the effective field (electrical current) from one point sample did not interfere with the fish catch at an adjacent point. Point markers were made up of small floats attached by rope to pieces of chain that form an anchor. The floats were marked with the depth (0.5. 1.0, 1.5 and 2.0 m) and with the letters A through E. Float identification was used to match specific habitat data with the fish data collected at a particular point. All habitat data was collected prior to sunset.

At each point, the following habitat values were measured and recorded on field data sheets (Table 9): substrate, cover, water temperature, water conductivity, oxygen,

and location (GPS). Coordinates of longitude and latitude were obtained from differential GPS positions (NAD83) using a Garmin GPSMAP 175. Laser range finders were used to record the distance from the point marker to shore. Dissolved oxygen, conductivity and water temperature were taken at mid-depth with a YSI (model 85) that measures oxygen, salinity, conductivity and temperature. For example, at a 1.0 m point sample, the habitat measurements were taken at 0.5 m. Substrate was classified using the same protocol for transect habitat sampling.

Macrophyte abundance was estimated visually in a one-metre radius around each point marker. Similar to transect sampling, macrophyte abundance was assigned to one of four categories: (0 %), sparse (1 to 19 %), moderate (20 to 70 %) or dense (>70 %). In addition, plant genera were recorded on the point habitat field sheet (Fassett 1966; Hotchkiss 1967) (Table 9) and classified in the same manner as substrate: dominant (>50 %), sub-dominant (10 to 50 %) and trace (<10 %). Dominant, sub-dominant and trace components of substrate were also recorded on the field data sheets.

All data elements on the point sampling habitat field data sheet (Table 9) are described in further detail in Appendix 3.

DATABASE DESCRIPTION

The Great Lakes' electrofishing database was initially created in Microsoft Access 2.0 (Moore et al. 1998). The software for this database was originally written in Microsoft Visual Basic 3.0 for the purpose of bulk data input, updates and extractions. The program was first moved to Visual Basic 6.0 and Access 97 then Access 2002 and is now a 32-bit application, with bulk loading replaced by interactive data entry (JEMSys Software Systems Inc 2003). The actual database is stored on a secure network drive, allowing different members of the project to have access to the data. The front-end user-interface (software for data entry and extraction) is stored on individual computer hard-drives. This software was developed in a way that allows easy data entry (field input screens are similar to field sheets) and also easy data manipulation within Microsoft Access. Data can be exported as text files (ext, tab, comma or space delimited) and easily imported into Microsoft Excel for further queries and analyses. Data from both habitat observations and fish catch data can be stored in the same

relational Access database. This arrangement has been useful for data analysis and for interpreting fish-habitat linkages.

Data from both habitat and fish catches were carefully entered into the database. Field sheets were initialed and dated by the individual entering the data (Tables 6, 7 and 9). After the data were entered, they were verified with the raw data from the field sheets. Errors were easily corrected and the data were re-saved. The field sheet was initialed and dated by the verifier. It takes approximately 40 to 50 minutes to enter habitat data from 20 point samples into the database. Entry of transect habitat data takes about 5 minutes per transect. The fish data entry time for both survey methods varied depending on the number of fish captured.

Data validation is immediate upon entry into the electrofishing database. The results of data validation are indicated by the background colour behind the data. A white background indicates that the data is correct. A yellow background indicates a warning which may be caused for example, in the individual tables by: missing lengths or weights, length or weight out of historical range, or an unavailable length-weight regression. A cyan or magenta-coloured background indicates a warning caused by a case exceeding confidence or prediction limits at P=0.05 and P=0.01, respectively. For example, an individual's weight exceeds prediction limits at length or for batch weights, mean weight deviates significantly from the mean of individual weights or historical geometric mean weight. A red background indicates an error caused by an invalid transect identification, invalid date, invalid time, invalid species code, non-numeric length or weight, or a missing count. Validation on the habitat assessment tables is less precise and is generally limited to checks such as positive numeric values where required, properly formatted dates and times, vaguely defined ranges for temperatures, start times preceding end times and habitat dates being different from the transect sampling dates. For more details, refer to Moore et al. (1998).

RELEVANCE OF ENVIRONMENTAL AND HABITAT MEASUREMENTS

This section explains the relevance and significance of the environmental measurements that are recorded during an electrofishing survey. Information that was recorded can be grouped into three categories: (1) *in situ* sampling information (i.e., weather, date, time and location), (2) water quality (chemistry and temperature) and (3) physical habitat characteristics. All of these factors can affect the fish catches at the time of survey. The environmental information is paramount for maintaining the integrity and usefulness of the data and to aid in interpreting the temporal and spatially variability of the fish catches. Standardization of procedures and controllable variables (e.g., electrical configuration and power output) are also important to minimize bias and variation due to gear and operational practices (Hine 1971; Jesien and Hocutt 1990; Kolz and Reynolds 1990; Harden and Conner 1992; Burkhardt and Gutreuter 1995; Kershner and Marschall 1998; Boner and Hubert 2002; Bayley and Austen 2002). In the following section, the potential effect of environmental and habitat data at the time of survey on fish distribution and electrofishing efficiency will be discussed.

SAMPLING INFORMATION

Weather: For safety reasons, weather was the first variable to consider prior to conducting an electrofishing survey. Rain, thunderstorms (lightning) and strong winds are unsuitable for electrofishing as wet electrical equipment greatly increases the hazard of shock (Reynolds 1996). In addition to safety, weather can affect other aspects of the survey, such as sampling efficiency and the distribution of fish. Rain and wind can affect electrofishing efficiency by disrupting surface visibility for netters and by affecting the balance/stability of netters at the bow (Reynolds 1996). Other uncontrollable factors, such as a cold front, storm or the moon cycle can cause abrupt changes in fish distribution. For example, wind speed and barometric pressure were found to be correlated with movements of black crappie (Guy et al., 1992). Springtime frontal systems have been found to cause adult fish tending nests to temporarily move, resulting in reduced catch rates (Reynolds 1996). Climatic conditions can also determine the presence or absence of certain species, and weather conditions at the time of the survey should be recorded.

Season (Date): Both season and date are important factors to record when conducting a fish survey. Seasonal fluctuations in water levels, temperature,

conductivity, macrophyte cover, primary productivity, and abundance of food will stimulate movement in fish and therefore affect catch rates (Zalewski and Cowx 1990). The potential impact of these factors on catch efficiency and fish distribution will be discussed later.

Species that seasonally or diurnally inhabit the shoreline such as centrarchids, cyprinids, and percids can be more vulnerable to electrofishing during these times (e.g., spawning, feeding) than benthic or pelagic species (Reynolds 1996). Spring often brings many life stages to the warmer inshore waters and it has been considered a good time for sampling. Autumn can also be considered a good time to sample adult pelagic fish as they move inshore to spawn or feed before returning to deeper waters to over-winter.

Day vs. Night: It is important to record the time of fish capture to determine the effects of light intensity on fish catch. Despite high catch rates at night because of increased visibility (fish are easier to see), the differences between day and night catches can depend on many factors: species of fish, size, area (littoral vs. profundal), habitat and season (Paragamian 1989; Pierce et al. 2001). Many researchers have documented higher catch rates at night than in the day (Scott and Crossman 1973; Prophet et al., 1989; Murphy and Willis 1996; Dumont and Dennis, 1997; Pierce et al., 2001). For example, walleye (*Sander vitreus*) prefer dark or turbid waters and low light conditions. Like many predators, walleye venture into the shallows to feed under the cover of darkness (Scott and Crossman 1973; Prophet et al 1989; Imbrock et al., 1996). Many species of fish are more active at night as the darkness acts as cover (Copp and Jurajda 1993, Reynolds 1996). Black crappies movements are also diel, but these fish move from the shallow waters in daytime to deeper offshore waters at night to feed (Guy et al., 1992). Other studies have concluded that fish moved to deeper waters during the day where they were highly aggregated and patchy, but returned to the shallows at night where they were highly dispersed (Helfman 1981; Paragamian 1989; Appenzeller and Leggett 1992). For example, golden shiners used the nearshore areas as feeding grounds and for refuge but during the daylight hours they moved to deeper waters (Scott and Crossman 1973). In our experience on the Great Lakes, day and night catches differed, particularly in littoral areas with little or no structure (Brousseau and Clark, pers. obser, GLLFAS).

Global Positioning System (GPS): Position data were collected at transects or point sample locations during each survey. Geo-referencing each study site created opportunities for ongoing site analysis, long-term monitoring, map creation and the

determination of spatial linkages between fish and their habitat. Geo-referencing also allowed data sharing with other projects. When possible, the collection of differential GPS (DGPS) data is preferred. A differential antenna allows a GPS receiver to link to a Canadian Coast Guard (CCG) reference station and therefore, increases the accuracy of positions. The reference station will correct errors in the GPS signal and transmit these corrections to receivers within the CCG or United States Geological Survey coverage area. With differential correction, accuracy was horizontally 10 metres or better, 95% of the time (Canadian Coast Guard, 2001). The Canadian DGPS augments the Navstar Global Positioning System (GPS) by providing localized range correction factors and auxiliary information that are broadcasted over a network of marine radio beacons.

WATER QUALITY

Conductivity: Water conductivity is a measure of the quality of water for electrical transmission (Reynolds 1996) and can affect electrofishing operations. Water conductivity is linearly correlated with total ion concentration (total dissolved solids, TDS) and water temperature. Conductivity is only an approximate measure of TDS because it is calibrated with potassium chloride (KCl in parts per million) rather than sodium chloride (NaCl in micro-siemens-μS/cm).

Conductivity was measured and recorded at each sampling point. A target current output of about 8 amperes (standardized) was maintained by adjusting the voltage (percent of range). Changes in water conductivity can affect an electrofishing operation in two ways: (1) by directly affecting the total current of the electrode system and (2) by affecting the division of current between the water and the fish (Zalewski and Cowx 1990). Extreme high (1000 μScm^{-1}) or low (30 μScm^{-1}) conductivity values will exceed the capacity of most power sources and reduce catch efficiency (Reynolds 1996). In the lower Great Lakes, the range of water conductivity was usually in the range (200 to 600 μScm^{-1}) needed for effective electrofishing. For this range, Bayley and Austen (2002) did not detect a significant effect of conductivity on the catchability of any fish group.

Water Clarity: The ability to see and attract stunned fish is a factor that affects electrofishing catch efficiency (Zalewski and Cowx 1990). The depth at which light can penetrate the water column (i.e. secchi depth) depends upon suspended levels of organic and inorganic particles or phytoplankton and ambient light (McMahon et al.

1996; Murphy and Willis 1996). Low transparency can be the result of excessive turbidity or high phytoplankton densities due to nutrient enrichment. Low transparency can also have a limiting effect on primary productivity and macrophyte growth. In clear water, benthic species of fish tended to be caught more easily and catch efficiency was high. In contrast, shoaling species with no cover exhibited increased avoidance capabilities from a great distance, resulting in low catch efficiency (Zalewski and Cowx 1990). In turbid waters, stunned fish were less visible to netters. Bottom-dwelling, camouflaged, and small body fish were most difficult to catch when immobilized (Reynolds 1996).

Temperature and dissolved oxygen: Temperature and dissolved oxygen are important variables used for assessing water quality and habitat suitability. There is a negative relationship between water temperature and dissolved oxygen content and fish have distinct thermal optima and limits (Scott and Crossman 1973). The seasonal absence or fluctuation of suitable temperatures and dissolved oxygen levels can limit the success of a species or even exclude it entirely from an ecosystem (McMahon et al. 1996). Several researchers have found that diverse fish communities including sport fish (e.g., salmonids), percids (e.g., yellow perch), centrarchids (i.e. sunfish), and cyprinids were greater at sites where the average summer dissolved oxygen concentrations were greater than 5 mg/L than at sites where it was less (Davis 1975; Coble 1982; Rudstam and Magnuson 1985; Knights *et al.* 1995). Although many species of fish are found at dissolved oxygen levels below 5 mg/L (e.g., bluegills and black crappies; Knights *et al.*, 1995), the effects of suboptimal oxygen concentrations have been found to negatively effect fecundity, growth (e.g., size), swimming ability, and metabolism (Coble 1982). Salmonids tended to be more sensitive to dissolved oxygen levels than other fish groups and required that minimum levels of dissolved oxygen exceeded 6.0 mg/L (Davis 1975). In Hamilton Harbour, Lake Ontario (AOC), an anoxic hypolimnion prevents the re-establishment of a coldwater fishery and may also be negatively affecting the warm-water fishery through wind-generated upwelling of anoxic bottom water (Smokorowski et al., 1998). Fitzsimons (unpublished data) found levels of dissolved oxygen below 3 mg/L, 40% of the time in the Harbour after three years (1994-1996) of data collection (*in situ* logger placed at a depth of 5 m on an artificial reef). No fish were captured at the artificial reefs when the dissolved oxygen levels fell below 3 mg/L (Fitzsimons unpublished data; Smokorowski et al. 1998).

The thermal characteristics of an aquatic environment have both a controlling and limiting influence on fish of all life stages (larval, juvenile, and adult) by affecting metabolic rates, growth, reproductive success, and swimming speeds (Schlesinger and Regier 1983; Koppelman et al. 1988). Fish require minimum temperatures for growth and have optimal growth ranges in temperature. The optimal temperatures for Great Lakes fish species were found over a wide range and some examples included: northern pike (19°C), lake trout (10-16°C), brook trout (15-16°C), brown trout (13°C), rainbow trout (13-22°C), lake whitefish (12.7-14°C), white sucker (14.1-22.4°C), golden shiner (16.8-23.7°C), blacknose dace (24-34°C), pumpkinseed sunfish (24-32°C), rock bass (21-30°C), bluegill (30-31°C), largemouth bass (25-32°C), smallmouth bass (26°C), walleye (21-23°C), and yellow perch (20-21°C) (Niimi and Beamish 1974; Schlesinger and Regier 1983; Cincotta and Stauffer 1984; Rudstam and Magnuson 1985; Koppelman et al. 1988; Haynes 1995).

Temperature indirectly affects electrofishing by changing fish distribution. Adults typically moved shoreward to spawn with temperature increases, while extreme high temperatures forced fish into deeper water, away from the areas being electrofished (Reynolds 1996). Great Lakes' fish spawned over a variety of temperature ranges. Some examples included: northern pike (2-18°C), rainbow trout (1-18°C), longnose gar (19-29°C), bluntnose minnow (20-28°C), brown bullhead (14-29°C), pumpkinseed sunfish (13-29°C), largemouth bass (14-21°C), walleye (4-12°C), and yellow perch (7-22°C) (Lane et al. 1996c).

Extremely low or high temperatures can affect electrofishing efficiency; reactions of fish tended to be poor under 5°C and over 28°C (Lamarque 1990). High temperatures increased fish metabolism, resulting in an increased ability of fish to detect and escape an electrical field. Lower temperatures decreased the buoyancy of stunned fish, making netting fish more difficult. Alternatively, stunned fish may be easier to capture at low temperatures because they recover less quickly. Water temperature will be discussed further in the next section (see water depth).

FISH HABITAT

Habitat features affect the distribution of fish and to some extent, electrofishing catch efficiency. Water depth, substrate, and structure or cover provided important habitat for spawning, juvenile, and adult fish in the Great Lakes (Brown et al. 1995; Lane et al. 1996 a, b, c). Water depth has been categorized into depth classes between 0-1

m, 1-2 m, 2-5 m, 5-10 m, and greater than 10 m (Brown et al. 1995; Lane et al. 1996 a, b, c; MacRae and Jackson 2001). For the purposes of this report, only depths in the littoral zone (0-1 m, 1-2 m, and 2-5 m) will be discussed. Substrate was grouped into eight categories: bedrock, boulder, rubble, cobble, gravel, sand, silt and clay. Structure or cover was divided into three major categories: submergent vegetation, emergent vegetation, and logs and large rocks. Submergent and emergent vegetation was strongly linked to substrate categories of gravel, sand and silt.

Water depth: Temperature dictates the depth strata occupied by adult fishes and therefore, strongly influences fish distribution. Many adult fish occupy the littoral shallow water zone during all or some part of the year. However, coldwater fish such as salmonids (e.g., Coho salmon, lake and brook char) will only occupy shallow waters (0-2 m) in the winter or fall when water temperatures are low (Lane et al. 1996b). As soon as temperatures begin to rise, coldwater fish will move out to deeper waters. Other seasonal fish movements included those species (e.g., alewife, emerald shiner, rock and smallmouth bass) that moved into the nearshore (0-2 m) for the summer months. The majority of adult cyprinids (e.g., golden shiner, bluntnose minnow, and fathead minnow) inhabited shallow water similar to their nursery habitats. Other species of fish also inhabited shallow waters (0-2 m) for much of the time (e.g., bowfin, northern pike, brown bullhead, American eel, and slimy sculpin). Most centrarchids (e.g., pumpkinseed sunfish, largemouth bass, black crappie) and percids (e.g., yellow perch, johnny darter, logperch) occupied water depths between 0 and 5 m year round (Lane et al. 1996b). In addition to seasonal movements, some fish exhibited diel movements from shallow to deep waters.

For spawning adult fishes, 69 out of 131 Great Lakes species spawned in lentic habitats (Lane et al. 1996c). Sheltered, shallow areas warm quickly in the spring and water temperatures played an important role in determining where fish chose to spawn (Lane et al. 1996c). Many fish that spawned in water depths of 0-2 m were associated with macrophytes (e.g., bowfin, gizzard shad, common carp, northern pike, pumpkinseed sunfish, and largemouth bass). Other species spawned in 0-2 m depths without macrophytes (e.g., alewife, rainbow trout, emerald shiner, and smallmouth bass). It is important to note that many species of fish were vulnerable to sampling programs while concentrated in shallow waters during spawning and pre- and post-spawning migrations.

The majority of Great Lakes young-of-the-year (age 0) fish occupied water depths of 2 metres or less (Lane et al. 1996a). Some species (e.g., smallmouth bass

and alewife) were found in the warm, shallow waters during the spring and summer when there is an abundant supply of food. With the onset of cooler temperatures, these young fish moved to deeper waters (Lane et al. 1996a). Other age 0 fish spent the spring in water depths between 0-1 m (e.g., longnose gar, bowfin, and northern pike) and then moved to the 1-2 m strata in the fall. Many juvenile cyprinids (e.g., spottail shiner, bluntnose and fathead minnows), centrarchids (e.g., pumpkinseed sunfish, largemouth bass), and percids (e.g., yellow perch) spent the first year in 0-2 m water depth (Lane et al. 1996a).

The electrical field from an electrofishing boat will only effectively penetrate the water column to a depth of approximately 2.0 m. The effective field diminished at depths greater than 2 metres (C.Brousseau, pers. obs., GLLFAS). At depths exceeding 1.5 m, fish were more difficult to catch because of the length of the standard sampling nets (3 m) and the greater escape area (volume) available to fish. Catch efficiency was high in shallow water with less volume and chance of escape, where cover was limited and the effective field was strong enough to stun fish in the sample area (Saltveit 1990).

Substrate: Substrate is an important habitat feature that can affect the electrofishing catch in different ways: (1) coarse substrates provide refuge for fish during various life stages and (2) electrical conductance depends on the size of substrate. Both of these factors can affect the catchability of fish. Great Lakes' fish utilized a great variety of substrates as adults, juveniles and during spawning. The most commonly used substrates by all life-stages were gravel, sand, and silt (Lane et al. 1996b). Strong adult fish associations with particular substrates included: boulder (e.g., stonecat, smallmouth bass), cobble (e.g., rock bass, smallmouth bass), gravel (e.g., alewife, gizzard shad, spottail shiner, and killifish), sand, and silt (e.g., longnose gar, bowfin, northern pike, common carp, pumpkinseed sunfish, and yellow perch). A strong affinity of many species of adult and juvenile fish for sand and silt substrates was closely linked to the presence of aquatic vegetation (Lane et al. 1996b). Plant material provides protection from predators as well as food sources (i.e. prey). Juvenile fish typically found in association with sand and silt included longnose gar, bowfin, northern pike, cyprinids (e.g., golden shiner, emerald shiner, bluntnose minnow), brown bullhead, centrarchids (e.g., rock bass, pumpkinseed and bluegill sunfish, largemouth bass), and percids (e.g., yellow perch, walleye). Other juvenile fish (e.g., alewife, lake trout, smallmouth bass and slimy sculpin) found refuge among the cracks and crevices of boulders, rubble, and cobble (Lane et al. 1996b). Cobble, gravel, sand and silt were the most commonly used

spawning substrates by Great Lakes' fish (Lane et al. 1996b). The numbers of species that spawned on silt were influenced by species that spawn on submergent and emergent vegetation.

Fine substrates and organic debris are more conductive than course gravel and cobble bottoms with little organic content. Highly conductive bottom substrates (e.g. mud or silt) will often reduce the horizontal intensity (i.e. short circuit) of an electrical field by drawing the electrical field into the substrate (Reynolds 1996). Different substrates can also affect fish catchability. For example, large diameter rocks, boulders and cobble provided cover for fishes and may prevent their capture if stunned fish remain hidden in crevices instead of entering the water column. Fish such as rock bass (Centrarchidae) and sculpins (Cottidae) hid in these rocky areas (C.Brousseau; pers. obs., GLLFAS).

Macrophytes/Cover: Cover provides protection from environmental conditions (shade), protection from predators (refugia) and rich sources of invertebrate prey (Murphy and Willis 1996). The types of habitat cover include aquatic vegetation, coarse substrate (cobble and boulders), large woody debris (e.g. logs, root wads), and riparian and shoreline features (e.g. undercut banks and overhanging terrestrial vegetation) (McMahon et al 1996). All are important components of fish habitat. The type and density of macrophytes can determine the amount of cover that is available to fish. A number of factors such as photoperiod, water clarity and temperature, nutrients, depth and substrate size will determine the type and abundance of macrophytes that will grow in a particular area. Pure sand or gravel areas are not favorable for most macrophytes, as their roots cannot properly penetrate the substrate. Mixed substrates with a quantity of organic matter are optimal for plant growth (Newmaster et al. 1997). Certain species of adult fish are often associated with submergent and emergent macrophyte cover, such as bowfin, northern pike, golden shiner, brown bullhead, American eel, pumpkinseed sunfish, and largemouth bass (Lane et al. 1996 b,c). Other adult fish preferred logs or boulders as cover with little or no macrophytes (e.g., smallmouth bass, walleye, and slimy sculpin). Similarly, fry and juvenile fish of many species (cyprinids, centrarchids, and percids) found refuge and food among macrophytes in shallow marshes and coastal wetlands of the Great Lakes. Many species spawned amongst submergent and emergent vegetation (bowfin, northern pike, pumpkinseed sunfish, and yellow perch) while others preferred submerged woody debris and large rocks (smallmouth bass, lake trout) (Lane et al. 1996c).

The affinity of many species of fish to macrophytes and other structures (e.g., logs, woody debris) has the tendency to concentrate fish, making them vulnerable to electrofishing. Conversely, in areas of extremely dense cover, it can be difficult for the netters to see and recover narcotized fish.

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Table 1. Electrofishing survey locations, 1988-2001. The number of transects, points, samples and records are given for each survey location. Transects are the number of unique line transects at each location, samples are the number of surveys for all transects and dates for each location, and records are the number of individual fish measured for length and weight. Point samples were conducted at or adjacent to transects, with 5 samples at each of the 0.5, 1.0, 1.5, and 2.0 m depth contours, respectively (see text).

Survey location	Number of transects	Number of samples	Number of records	Years
		TRANSECTS		
Severn Sound, Georgian Bay				
Penetang	35	124	3,173	1990, 1992, 2002
Hog	20	65	1,890	1990, 1992, 1995, 2002
Sturgeon	12	23	396	1992
Matchedash	12	38	1,318	1990
Green Island	9	27	755	1995
Lake Erie				
Long Point	9	27	1,126	1994
Port Dover	16	48	790	1994
Port Colborne	22	66	605	1994
Lake Ontario, West				
Port Credit	9	10	345	1990
Port Weller	5	13	230	1994
Port Dalhousie	23	52	1,063	1994
Hamilton Harbour	99	1,279	38,091	1988,1990, 1992, 1995-1998, 2001, 2002
Burlington Waterfront	6	24	212	1994, 1999
Bronte Harbour	21	86	1,677	1994, 1998, 1999
Lake Ontario, East				
Presqu'ile Bay	10	30	978	1994
Trenton	10	52	2,412	1989, 1990, 1999
Belleville	9	53	2,772	1989, 1990, 1999
Big Island	14	103	4,145	1989, 1990, 1999, 2001
Hay Bay	8	20	263	1992
Camachan	9	41	1,695	1992, 1999
Conway	6	12	261	1992

Table 1 continued

Suvey location	Number of transects	Number of samples	Number of records	Years[1]
Lake Ontario, East				
Black River	6	62	3,071	1998, 1999, 2000, 2001
Little and McMahon Bluff	6	85	1,455	1998, 1999, 2000, 2001
West Lake	18	94	3,464	1998, 1999, 2002
Grand Total	**354**	**2,434**	**72, 187**	**1988 – 2001**
		POINTS		
Hamilton Harbour	6	303	1,149	2002
Bay of Quinte	7	278	1,376	2001
Little and MacMahon Bluffs	6	563	1,005	2000, 2001
Black River	6	394	2,166	2000, 2001
West Lake	12	320	1,038	2002
Grand Total	**37**	**1,858**	**6,734**	**2000-2002**

[1] not all transects were surveyed each year and the number of samples per transect each year varied from 1 to 6 (usually 2-4).

Table 2. Range in physical conditions during surveys at study locations in the lower Great Lakes (1988-2002).

Location	Macrophytes (% cover)	Conductivity Mean (range) ($\mu S\ cm^{-1}$)	Temperature Mean (range) (° C)
Severn Sound, Georgian Bay			
Penetang Harbour	1-100	197.2 (150.0-239.2)	24.8 (23.0-27.2)
Hog Bay	20-100	195.0 (145.0-257.1)	26.0 (23.0-29.5)
Matchedash	0-100	NA	NA
Green Island	0-100	238.5 (210.0-280.0)	NA
Sturgeon Bay	0-100	229.1 (160.0-270.0)	NA
Lake Erie			
Long Point	0-100	250.4 (220.0-295.0)	NA
Port Dover	0-100	261.5 (200.0-500.0)	NA
Port Colborne	0-100	262.5 (220.0-360.0)	NA
Lake Ontario, West			
Port Credit	NA	NA	NA
Port Weller	0-19	278.9 (260.0-305.0)	NA
Port Dalhousie	0-100	265.3 (240.0-305.0)	NA
Hamilton Harbour	0-100	546.6 (370.0-720.0)	22.1 (16.0-27.3)
Burlington waterfront	0	259.6 (220.0-360.0)	14.3 (10.7-17.7)
Bronte Harbour	0-100	264.7 (195.0-450.0)	15.9 (8.7-19.2)
Lake Ontario, East			
Presqu'ile Bay	20-100	254.2 (220.0-285.0)	NA
Trenton	1-100	223.1 (175.0-260.0)	25.6 (23.4-28.7)
Belleville	1-100	204.0 (150.0-250.0)	22.0 (11.0-27.0)
Big Island	0-100	218.2 (160.0-265.0)	20.7 (8.9-28.2)
Hay Bay	0-100	276.8 (255.0-300.0)	NA
Carnachan	1-100	250.9 (210.0-290.0)	23.0 (18.2-26.7)
Conway	0-100	210.0-290.0 (265.4)	NA
Black River	0-100	268.7 (210.0-413.6)	20.2 (14.4-24.9)
MacMahon Bluff	0	267.0 (236.7-360.0)	18.8 (14.1-22.4)
Little Bluff	0-20	266.8 (231.1-350.0)	19.0 (14.3-22.4)
West Lake	0-100	261.3 (200.0-330.0)	23.5 (14.1-29.1)

NA= not available

Table 3. Range in catch (numbers), biomass (kg), and species richness during surveys at study locations in the lower Great Lakes (1988-2002).

Location	Sample size (N)	Numbers	Biomass (kg)	Species richness
Severn Sound, Georgian Bay				
Penetang Harbour	124	36.2 (0-161)	3.64 (0.00-21.19)	4.9 (0-12)
Hog Bay	65	38.2 (0-166)	3.85 (0.00-34.82)	5.3 (0-10)
Matchedash	38	47.8 (7-170)	3.89 (1.32-12.09)	7.0 (4-12)
Green Island	27	36.9 (2-138)	2.77 (0.01-8.20)	6.4 (1-10)
Sturgeon Bay	23	17.5 (0-50)	1.88 (0.00-9.98)	4.3 (0-8)
Lake Erie				
Long Point	27	43.2 (1-141)	2.52 (0.01-7.49)	8.5 (1-15)
Port Dover	48	19.5 (0-149)	3.30 (0.00-14.46)	4.4 (0-13)
Port Colborne	66	9.3 (0-75)	2.96 (0.00-17.72)	2.8 (0-9)
Lake Ontario, West				
Port Credit	10	117.5 (7-309)	11.67 (0.19-24.68)	4.1 (1-9)
Port Weller	13	32.1 (2-120)	3.02 (0.11-9.61)	4.1 (2-6)
Port Dalhousie	52	34.4 (0-182)	6.01 (0.00-48.11)	4.3 (0-10)
Hamilton Harbour	1279	53.4 (0-332)	8.65 (0.00-89.00)	5.1 (0-15)
Burlington waterfront	24	34.4 (0-174)	1.30 (0.00-13.75)	1.6 (0-5)
Bronte Harbour	86	63.5 (0-804)	3.90 (0.00-50.67)	2.7 (0-10)
Lake Ontario, East				
Presqu'ile Bay	30	38.9 (3-88)	2.53 (0.06-9.21)	5.8 (1-11)
Trenton	52	88.1 (0-541)	7.06 (0.00-20.86)	7.7 (0-14)
Belleville	53	91.6 (1-277)	6.42 (0.05-30.14)	8.0 (1-14)
Big Island	103	64.6 (0-376)	3.84 (0.00-14.59)	7.2 (0-14)
Hay Bay	18	17.9 (3-107)	3.48 (0.28-11.71)	5.3 (2-9)
Carnachan	41	44.2 (5-134)	3.30 (0.27-8.72)	6.8 (2-10)
Conway	12	23.0 (0-65)	3.67 (0.00-17.25)	4.8 (0-9)
Black River	61	65.3 (0-224)	4.10 (0.00-17.34)	7.4 (0-15)
MacMahon Bluff	44	21.2 (1-82)	1.30 (0.01-4.62)	5.0 (1-10)
Little Bluff	41	17.7 (0-74)	0.76 (0.00-2.28)	3.3 (0-7)
West Lake	94	41.4 (0-131)	1.92 (0.00-7.61)	7.3 (0-12)

Table 4a. Presence(x) or absence of fish species at electrofishing transects from 1988-2002 for each of the following locations in the Bay of Quinte and Prince Edward County: TRENT= Trenton; BELL= Belleville; CARN= Carnachan Bay; BIGI= Big Island; HAYB= Hay Bay; CONW= Conway; WLAK= West Lake; LBLF= Little Bluff, MBLF= MacMahon Bluff; and BRIV= Black River.

Common names	Scientific names	TRENT	BELL	CARN	BIGI	HAYB	CONW	WLAK	LBLF	MBLF	BRIV
Sea lamprey	*Petromyzon marinus*										
Longnose gar	*Lepisosteus osseus*		x		x			x			x
Bowfin	*Amia calva*	x	x	x	x	x		x		x	x
Alewife	*Alosa pseudoharengus*	x	x	x	x	x	x	x	x	x	x
Gizzard shad	*Dorosoma cependianum*	x	x	x	x	x		x			x
Coho salmon	*Oncorhynchus kisutch*										
Chinook salmon	*Oncorhynchus tshawytscha*										
Rainbow trout	*Oncorhynchus mykiss*									x	
Brown trout	*Salmo trutta*								x		
Lake trout	*Salvelinus namaycush*									x	
Lake whitefish	*Coregonus clupeaformis*							x			
Rainbow smelt	*Osmerus mordax*				x						
Northern pike	*Esox lucius*	x	x	x	x	x		x		x	x
Muskellunge	*Esox masquinongy*										
Grass pickerel	*Esox americanus vermiculatus*							x			
Chain pickerel	*Esox niger*	x						x			
Central mudminnow	*Umbra limi*	x	x					x			
Quillback	*Carpiodes cyprinus*										
White sucker	*Catostomus commersoni*	x	x	x	x	x	x	x	x	x	x
Lake chubsucker	*Erimyzon sucetta*										
Bigmouth buffalo	*Ictiobus cyprinellus*										
Silver redhorse	*Moxostoma anisurum*	x	x		x						
Golden redhorse	*Moxostoma erythrurum*										
Shorthead redhorse	*Moxostoma macrolepidotum*	x	x								
River redhorse	*Moxostoma carinatum*	x									
Redhorse sp	*Moxostoma sp.*		x								
Golfish	*Carassius auratus*										
Lake chub	*Couesius plumbeus*										
Common carp	*Cyprinus carpio*	x	x	x	x			x			x
Eastern silvery minnow	*Hybognathus regius*										
Golden shiner	*Notemigonus crysoleucas*	x	x	x	x	x	x	x		x	x
Emerald shiner	*Notemigonus atherinoides*	x	x		x	x	x	x	x	x	x
Common shiner	*Luxilus cornutus*				x						
Blackchin shiner	*Notropis heterodon*				x			x		x	
Blacknose shiner	*Notropis heterolepis*							x			
Spottail shiner	*Notropis hudsonius*	x	x	x	x	x	x	x	x	x	x
Bluntnose minnow	*Pimephales notatus*	x	x	x	x			x	x	x	x
Fathead minnow	*Pimephales promelas*	x	x	x	x			x	x	x	x
Blacknose dace	*Rhinichthys atratulus*								x		x

Table 4a continued

Common names	Scientific names	TRENT	BELL	CARN	BIGI	HAYB	CONW	WLAK	LBLF	MBLF	BRIV
Longnose dace	*Rhinichthys cataractae*										x
Creek chub	*Semotilus atromaculatus*							x	x	x	x
Black bullhead	*Ameiurus melas*										
Brown bullhead	*Ameiurus nebulosus*	x	x	x	x	x	x	x		x	x
Channel catfish	*Ictalurus punctatus*				x						
Stonecat	*Notorus flavus*								x		
Tadpole madtom	*Notorus gyrinus*								x		
American eel	*Anguilla rostrata*	x	x	x	x	x	x		x	x	x
Banded killifish	*Fundulus diaphanous*	x	x	x	x			x	x	x	x
Threespine stickleback	*Gasterosteus aculeatus*								x	x	x
Fourspine stickleback	*Apeltes quadracus*									x	
Trout-perch	*Percopsis omiscomaycus*							x		x	
White perch	*Morone Americana*	x	x		x	x	x	x			
White bass	*Morone chrysops*		x		x	x	x				x
Rock bass	*Ambloplites rupestris*	x	x	x	x	x	x	x	x	x	x
Green sunfish	*Lepomis cyanellus*										
Pumpkinseed	*Lepomis gibbosus*	x	x	x	x	x	x	x	x	x	x
Bluegill	*Lepomis macrochirus*	x	x	x	x			x		x	x
Smallmouth bass	*Micropterus dolomieu*	x	x	x	x			x	x	x	x
Largemouth bass	*Micropterus salmoides*	x	x	x	x		x	x	x	x	x
Black crappie	*Pomoxis nigromaculatus*	x	x		x			x		x	x
Yellow perch	*Perca flavescens*	x	x	x	x	x	x	x	x	x	x
Walleye	*Sander vitreus*	x	x	x	x	x	x	x			
Fantail darter	*Etheostoma flabellare*							x	x		
Johnny darter	*Etheostoma nigrum*	x	x		x				x	x	x
Logperch	*Percina caprodes*	x	x	x	x		x		x	x	
Brook silverside	*Labidesthes sicculus*	x	x	x	x			x		x	x
Round goby	*Neogobius melanostomus*										
Freshwater drum	*Aplodinotus grunniens*	x	x		x	x	x				x
Slimy sculpin	*Cottus cognatus*								x	x	x
Sculpins	*Cottus sp.*										x
Hybrid (goldfish x carp)	C. *auratus* x C. *carpio*										
Hybrid (pumpkinseed x bluegill)	L. *gibbosus* x L. *macrochirus*										
Cumlative number of species:		**32**	**33**	**22**	**34**	**17**	**16**	**33**	**23**	**30**	**32**

Table 4b. Presence (x) or absence of fish species at electrofishing transects from 1988-2002 for each of the following locations in western Lake Ontario: HAMH= Hamilton Harbour; PDAL= Port Dalhousie; PCRD= Port Credit; BRON= Bronte Harbour; BURL= Burlington Beach; PRES= Presqu'ile' and PWEL= Port Weller.

Common names	Scientific names	HAMH	PDAL	PCRD	BRON	BURL	PRES	PWEL
Sea lamprey	*Petromyzon marinus*						x	
Longnose gar	*Lepisosteus osseus*	x					x	
Bowfin	*Amia calva*	x					x	x
Alewife	*Alosa pseudoharengus*	x	x	x	x	x	x	x
Gizzard shad	*Dorosoma cependianum*	x	x	x	x		x	
Coho salmon	*Oncorhynchus kisutch*				x			
Chinook salmon	*Oncorhynchus tshawytscha*	x	x	x	x	x		
Rainbow trout	*Oncorhynchus mykiss*	x	x		x	x		
Brown trout	*Salmo trutta*	x	x	x	x			
Lake trout	*Salvelinus namaycush*	x				x		
Lake whitefish	*Coregonus clupeaformis*				x			
Rainbow smelt	*Osmerus mordax*	x	x	x	x	x		
Northern pike	*Esox lucius*	x	x	x			x	
Muskellunge	*Esox masquinongy*							
Grass pickerel	*Esox americanus vermiculatus*						x	
Chain pickerel	*Esox niger*							
Central mudminnow	*Umbra limi*							
Quillback	*Carpiodes cyprinus*							
White sucker	*Catostomus commersoni*	x	x	x	x	x	x	x
Lake chubsucker	*Erimyzon sucetta*							
Bigmouth buffalo	*Ictiobus cyprinellus*	x						
Silver redhorse	*Moxostoma anisurum*	x						
Golden redhorse	*Moxostoma erythrurum*							x
Shorthead redhorse	*Moxostoma macrolepidotum*	x	x	x	x			
River redhorse	*Moxostoma carinatum*		x					
Redhorse sp	*Moxostoma sp.*							
Golfish	*Carassius auratus*	x						
Lake chub	*Couesius plumbeus*							x
Common carp	*Cyprinus carpio*	x	x	x	x	x	x	x
Eastern silvery minnow	*Hybognathus regius*							
Golden shiner	*Notemigonus crysoleucas*	x			x		x	
Emerald shiner	*Notemigonus atherinoides*	x	x	x	x	x		x
Common shiner	*Luxilus cornutus*	x						
Blackchin shiner	*Notropis heterodon*	x						
Blacknose shiner	*Notropis heterolepis*						x	x
Spottail shiner	*Notropis hudsonius*		x		x	x	x	x
Bluntnose minnow	*Pimephales notatus*	x					x	
Fathead minnow	*Pimephales promelas*	x						
Blacknose dace	*Rhinichthys atratulus*	x						

Table 4b continued

Common names	Scientific names	HAMH	PDAL	PCRD	BRON	BURL	PRES	PWEL
Longnose dace	*Rhinichthys cataractae*							
Creek chub	*Semotilus atromaculatus*							
Black bullhead	*Ameiurus melas*	x						
Brown bullhead	*Ameiurus nebulosus*	x	x		x		x	
Channel catfish	*Ictalurus punctatus*	x						
Stonecat	*Notorus flavus*							
Tadpole madtom	*Notorus gyrinus*	x					x	
American eel	*Anguilla rostrata*	x	x		x	x		x
Banded killifish	*Fundulus diaphanous*							
Threespine stickleback	*Gasterosteus aculeatus*	x			x			
Fourspine stickleback	*Apeltes quadracus*							
Trout-perch	*Percopsis omiscomaycus*	x	x		x	x		x
White perch	*Morone Americana*	x			x	x		x
White bass	*Morone chrysops*	x	x		x			x
Rock bass	*Ambloplites rupestris*	x	x		x		x	x
Green sunfish	*Lepomis cyanellus*	x						
Pumpkinseed	*Lepomis gibbosus*	x	x	x	x		x	
Bluegill	*Lepomis macrochirus*	x	x				x	
Smallmouth bass	*Micropterus dolomieu*	x	x		x			x
Largemouth bass	*Micropterus salmoides*	x	x	x	x		x	
Black crappie	*Pomoxis nigromaculatus*	x	x	x	x		x	
Yellow perch	*Perca flavescens*	x	x	x	x	x	x	x
Walleye	*Sander vitreus*	x	x	x			x	x
Fantail darter	*Etheostoma flabellare*							
Johnny darter	*Etheostoma nigrum*	x			x			
Logperch	*Percina caprodes*	x	x		x			
Brook silverside	*Labidesthes sicculus*	x	x		x		x	
Round goby	*Neogobius melanostomus*	x						
Freshwater drum	*Aplodinotus grunniens*	x	x		x			x
Slimy sculpin	*Cottus cognatus*				x			
Sculpins	*Cottus sp.*							
Hybrid (goldfish x carp)	C. *auratus* x C. *carpio*	x	x					
Hybrid (pumpkinseed x bluegill)	L. *gibbosus* x L. *macrochirus*	x						
Cumulative number of species:		**48**	**29**	**15**	**31**	**13**	**22**	**18**

Table 4c. Presence (x) or absence of fish species at electrofishing transects from 1988-2002 for each of the following locations in Georgian Bay and Lake Erie: HOGB= Hog Bay; PENE= Penetang Harbour; MATB= Matchedash Bay; GRIS= Green Island; STUB= Sturgeon Bay; PCOL= Port Colbourne; PDOV= Port Dover; and LONG= Long Point.

Common names	Scientific names	HOGB	PENE	MATB	GRIS	STUB	PCOL	PDOV	LONG
Sea lamprey	*Petromyzon marinus*				x				
Longnose gar	*Lepisosteus osseus*	x	x						
Bowfin	*Amia calva*	x	x	x	x	x	x	x	x
Alewife	*Alosa pseudoharengus*	x	x	x	x	x		x	
Gizzard shad	*Dorosoma cependianum*			x	x		x	x	
Coho salmon	*Oncorhynchus kisutch*								
Chinook salmon	*Oncorhynchus tshawytscha*			x					
Rainbow trout	*Oncorhynchus mykiss*								
Brown trout	*Salmo trutta*								
Lake trout	*Salvelinus namaycush*								
Lake whitefish	*Coregonus clupeaformis*								
Rainbow smelt	*Osmerus mordax*		x				x		
Northern pike	*Esox lucius*	x	x	x	x	x	x	x	x
Muskellunge	*Esox masquinongy*	x							
Grass pickerel	*Esox americanus vermiculatus*								x
Chain pickerel	*Esox niger*								
Central mudminnow	*Umbra limi*		x						
Quillback	*Carpiodes cyprinus*		x	x			x	x	
White sucker	*Catostomus commersoni*	x	x	x	x	x	x	x	
Lake chubsucker	*Erimyzon sucetta*								x
Bigmouth buffalo	*Ictiobus cyprinellus*								
Silver redhorse	*Moxostoma anisurum*		x				x		
Golden redhorse	*Moxostoma erythrurum*			x					
Shorthead redhorse	*Moxostoma macrolepidotum*		x		x		x	x	
River redhorse	*Moxostoma carinatum*						x		
Redhorse sp	*Moxostoma sp.*					x			
Golfish	*Carassius auratus*		x	x			x		
Lake chub	*Couesius plumbeus*								
Common carp	*Cyprinus carpio*	x	x	x	x		x	x	x
Eastern silvery minnow	*Hybognathus regius*	x							
Golden shiner	*Notemigonus crysoleucas*	x	x	x	x	x		x	x
Emerald shiner	*Notemigonus atherinoides*		x				x	x	
Common shiner	*Luxilus cornutus*	x	x						
Blackchin shiner	*Notropis heterodon*	x	x		x				x
Blacknose shiner	*Notropis heterolepis*	x	x	x					
Spottail shiner	*Notropis hudsonius*	x	x	x	x	x	x	x	
Bluntnose minnow	*Pimephales notatus*	x		x	x				x
Fathead minnow	*Pimephales promelas*								
Blacknose dace	*Rhinichthys atratulus*								

Table 4c continued

Common names	Scientific names	HOGB	PENE	MATB	GRIS	STUB	PCOL	PDOV	LONG
Longnose dace	*Rhinichthys cataractae*								
Creek chub	*Semotilus atromaculatus*	x	x						
Black bullhead	*Ameiurus melas*								
Brown bullhead	*Ameiurus nebulosus*	x	x	x	x	x	x	x	x
Channel catfish	*Ictalurus punctatus*							x	
Stonecat	*Notorus flavus*		x						
Tadpole madtom	*Notorus gyrinus*								
American eel	*Anguilla rostrata*						x	x	
Banded killifish	*Fundulus diaphanous*		x						x
Threespine stickleback	*Gasterosteus aculeatus*								
Fourspine stickleback	*Apeltes quadracus*								
Trout-perch	*Percopsis omiscomaycus*		x						
White perch	*Morone Americana*		x		x				
White bass	*Morone chrysops*		x	x					
Rock bass	*Ambloplites rupestris*	x	x	x	x	x	x	x	x
Green sunfish	*Lepomis cyanellus*								
Pumpkinseed	*Lepomis gibbosus*	x	x	x	x	x	x	x	x
Bluegill	*Lepomis macrochirus*	x					x	x	x
Smallmouth bass	*Micropterus dolomieu*	x	x	x	x	x	x	x	
Largemouth bass	*Micropterus salmoides*	x	x	x	x	x	x	x	x
Black crappie	*Pomoxis nigromaculatus*	x	x	x	x	x	x	x	x
Yellow perch	*Perca flavescens*	x	x	x	x	x	x	x	x
Walleye	*Sander vitreus*	x	x	x	x				
Fantail darter	*Etheostoma flabellare*								
Johnny darter	*Etheostoma nigrum*								
Logperch	*Percina caprodes*			x	x			x	
Brook silverside	*Labidesthes sicculus*	x	x		x		x	x	x
Round goby	*Neogobius melanostomus*								
Freshwater drum	*Aplodinotus grunniens*						x	x	x
Slimy sculpin	*Cottus cognatus*								
Sculpins	*Cottus sp.*								
Hybrid (goldfish x carp)	C. *auratus* x C. *carpio*						x	x	
Hybrid (pumpkinseed x bluegill)	L. *gibbosus* x L. *macrochirus*								
Cumulative number of species:		**25**	**33**	**24**	**23**	**14**	**25**	**25**	**18**

Table 5a. Example of average and maximum catch of fish by transect and point survey from Prince Edward Bay, Lake Ontario in 2000 and 2001. For both catch (total number of fish) and species richness, the number of samples (n), maximum (max), mean, and standard error of the mean (SE) are given. For each transect sampled, 15 to 20 points were sampled to equal the numbers of samples (n).

			Catch			Species Richness		
Year	Survey Method	n	Max	Mean	SE	Max	Mean	SE
2000	Transect	35	131	38.6	5.6	11	5.3	0.5
2001	Transect	37	180	39.0	7.2	15	6.7	0.5
2000	Point	566	39	3.4	0.2	7	1.6	0.1
2001	Point	669	35	4.0	0.2	8	1.8	0.1

Table 5b. Comparison of mean catch (number of fish) and average species richness (number of fish species) at areas with and without macrophytes in eastern Lake Ontario (2000-2001). Taken from (Boston et al. 2002). The samples were collected by boat electrofishing using point and line transect survey methods. The number of samples required to produce a coefficient of variation of the mean of 0.20 is indicated, along with the effort (hours) needed to collect the samples.

		Catch			Species richness		
Study Area	Survey Method	Mean	N[1]	Effort[2] (h)	Mean	N	Effort (h)
A (macrophytes)	Point	5	27 (24)	3-4	2.3	12 (10)	1-2
	Transect	66	13 (12)	12-14	7.3	4 (3)	3-4
B (no macrophytes)	Point	2	35 (32)	3-4	1.0	27 (26)	3-4
	Transect	24	18 (16)	17-20	4.6	6 (5)	5-6

[1] N was estimated using the formula: $N=aX^{b-2}CV_x^{-2}$ (Cyr et al. 1992), where a and b are coefficients from the regression of variance versus mean catch and species richness for the electrofishing samples, and CV_x is the desired coefficient of variation of the mean.
[2] Effort (approximate, in hours) required for collecting the fish and habitat data.

Table 6. Electrofishing fish field data sheet

Productive Capacity: Fish Field Data Sheet Sheet ____ of ____

Location:	Date: (DD/MM) 2002	Transect:	Time (24hr): Start	Finish	Shocker Seconds

Time Period ☐ Before Dusk ☐ After Dusk	Amps	Volts	Percent of Range: %	Wind Speed (0-9, in increments of 5km/hr)	Wind Direction (1=N,2=E,3=S,4=W)

Measure a maximum of 20 individuals per species. After 20 individuals, group fish into batches and record in the Batch section below.

Id #	SPP	F.L. (mm.)	Wt. (gm.)	Sex	Scale#	Depth/Marker
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

Id #	SPP	F.L. (mm.)	Wt. (gm.)	Sex	Scale#	Depth/Marker
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						
35						
36						
37						
38						
39						
40						

Batches

SPP	Number of Fish	Batch Weight (gm.)

SPP	Number of Fish	Batch Weight (gm.)

SPP	Number of Fish	Batch Weight (gm.)

Notes

☐ Continued on Back

Enter dates and initials when data entered in computer.

	Date	Init
Entered		
Verified		
Corrected		

Table 7. Transect habitat assessment field data sheet.

Productive Capacity: Transect Habitat Field Data Sheet

Location:	Date: (DD/MM) 2002	Transect:	Time (24hr):

Temperature, Conductivity, Dissolved Oxygen, and Secchi Depth Readings

Mid Transect		Temp (°C)	Conductivity (µS/cm.)	Dissolved Oxygen (mg/L)
Secchi Depth (m)	Surface			
	0.75 m.			
	1.5 m.			

At 5m. depth near transect		Temp (°C)	Conductivity (µS/cm.)	Dissolved Oxygen (mg/L)
Secchi Depth (m)	Surface			
	2.5 m.			
	5 m.			

Echogram Times

Start (24hr.) End (24hr.)

Echosounder Settings: (Default Values in brackets)

Pulse Width (30): Discrimination (0): Surface Clutter (1): Paper Speed (5):

Transect Marker Descriptions

Accuracy of Coordinates: (Check appropriate box) ☐ Approximate ☐ Non-DifferentialGPS ☐ Differential GPS

Marker #1	Degrees	Minutes
Latitude (dd mm.mmm)		
Longitude (dd mm.mmm)		

Orientation of marker (N,S,E,W)

Distance to shore (m.)

Sediment Categories	Organic	Marl/gyttja	Clay	Silt	Sand	Gravel	Rubble	Cobble	Boulder	Bedrock	Mussels	Other
Dominant												
Sub-Dom.												
Trace												

Type of Other

Marker Description

Waypoint Name

Marker #2	Degrees	Minutes
Latitude (dd mm.mmm)		
Longitude (dd mm.mmm)		

Orientation of marker (N,S,E,W)

Distance to shore (m.)

Sediment Categories	Organic	Marl/gyttja	Clay	Silt	Sand	Gravel	Rubble	Cobble	Boulder	Bedrock	Mussels	Other
Dominant												
Sub-Dom												
Trace												

Type of Other

Marker Description

Waypoint Name

Macrophyte Cover

Macrophyte Observer: ☐ None ☐ Sparse ☐ Moderate ☐ Dense

Names of dominant vegetation types

Notes:

Comments

Enter dates and initials when data entered in computer

	Date	Init.
Entered		
Verified		
Corrected		

Table 8. Settings for the Lowrance X-16 echosounder used in habitat surveys to record depth and macrophyte density (from Valere 1996).

Lowrance X-16 setting	Electrofishing Transect
Sensitivity	Minimum
Grayline	4
Print Intensity	1
Paper Speed	5 (2.1 in/min)
Scale*	0-2 m
Pulse Width	30 μs (Dense Vegetation)
	110 μs (Sparse Vegetation)
Suppression	0
Discrimination**	0 to 4
Surface Clutter**	1 to 7

* scale of the echogram was chosen to optimize the size of the tracing (i.e. largest possible tracing, that still included the deepest part of the transect).

** these settings were set at minimum and increased accordingly to optimize the readability of the echogram. Conditions such as rough water, extremely abundant vegetation, bubbles under the boat, etc., may have warranted the increase of one or both settings.

Table 9. Point sample habitat assessment field data sheet

Productive Capacity: Point Habitat Field Data Sheet

Location: | Date (DD/MM): 2002

Transect | Point Location (Degrees, Minutes) | Sediment Categories

Depth (m.) | Time (24 Hr) | Distance to shore (m):

Latitude (dd mm.mmm) | Longitude (dd mm.mmm)

Sediment Categories: Organic, Hardpan Clay, Silt, Sand, Gravel, Rubble, Cobble, Boulder, Bedrock, Mussels, Other, Type of Other

Dominant | Sub-Dom. | Trace

Mid-Depth Water Conditions: Temp (°C) | Conductivity (µS/cm.) | Dissolved Oxygen (mg/L)

Macrophyte Density: ☐ None ☐ Sparse ☐ Moderate ☐ Dense

Macrophyte Composition: Hydrocharis, Vallisneria, Myriophyllum, Elodea, Potamogeton, Bidens, Ranunculus, Utricularia, Naja, Narrow Pot., Broad Pot., Low Pot., Moss, Chara, Typha, Scirpus, Juncus, Sagittaria, Pontederia, Other, Type of Other

Dominant | Sub-Dom. | Trace

Transect | Point Location (Degrees, Minutes) | Sediment Categories

Depth (m.) | Time (24 Hr) | Distance to shore (m):

Latitude (dd mm.mmm) | Longitude (dd mm.mmm)

Sediment Categories: Organic, Hardpan Clay, Silt, Sand, Gravel, Rubble, Cobble, Boulder, Bedrock, Mussels, Other, Type of Other

Dominant | Sub-Dom. | Trace

Mid-Depth Water Conditions: Temp (°C) | Conductivity (µS/cm.) | Dissolved Oxygen (mg/L)

Macrophyte Density: ☐ None ☐ Sparse ☐ Moderate ☐ Dense

Macrophyte Composition: Hydrocharis, Vallisneria, Myriophyllum, Elodea, Potamogeton, Bidens, Ranunculus, Utricularia, Naja, Narrow Pot., Broad Pot., Low Pot., Moss, Chara, Typha, Scirpus, Juncus, Sagittaria, Pontederia, Other, Type of Other

Dominant | Sub-Dom. | Trace

Transect | Point Location (Degrees, Minutes) | Sediment Categories

Depth (m.) | Time (24 Hr) | Distance to shore (m):

Latitude (dd mm.mmm) | Longitude (dd mm.mmm)

Sediment Categories: Organic, Hardpan Clay, Silt, Sand, Gravel, Rubble, Cobble, Boulder, Bedrock, Mussels, Other, Type of Other

Dominant | Sub-Dom. | Trace

Mid-Depth Water Conditions: Temp (°C) | Conductivity (µS/cm.) | Dissolved Oxygen (mg/L)

Macrophyte Density: ☐ None ☐ Sparse ☐ Moderate ☐ Dense

Macrophyte Composition: Hydrocharis, Vallisneria, Myriophyllum, Elodea, Potamogeton, Bidens, Ranunculus, Utricularia, Naja, Narrow Pot., Broad Pot., Low Pot., Moss, Chara, Typha, Scirpus, Juncus, Sagittaria, Pontederia, Other, Type of Other

Dominant | Sub-Dom. | Trace

Transect | Point Location (Degrees, Minutes) | Sediment Categories

Depth (m.) | Time (24 Hr) | Distance to shore (m):

Latitude (dd mm.mmm) | Longitude (dd mm.mmm)

Sediment Categories: Organic, Hardpan Clay, Silt, Sand, Gravel, Rubble, Cobble, Boulder, Bedrock, Mussels, Other, Type of Other

Dominant | Sub-Dom. | Trace

Mid-Depth Water Conditions: Temp (°C) | Conductivity (µS/cm.) | Dissolved Oxygen (mg/L)

Macrophyte Density: ☐ None ☐ Sparse ☐ Moderate ☐ Dense

Macrophyte Composition: Hydrocharis, Vallisneria, Myriophyllum, Elodea, Potamogeton, Bidens, Ranunculus, Utricularia, Naja, Narrow Pot., Broad Pot., Low Pot., Moss, Chara, Typha, Scirpus, Juncus, Sagittaria, Pontederia, Other, Type of Other

Dominant | Sub-Dom. | Trace

Enter dates and initials when data entered in computer | Entered | Verified | Corrected

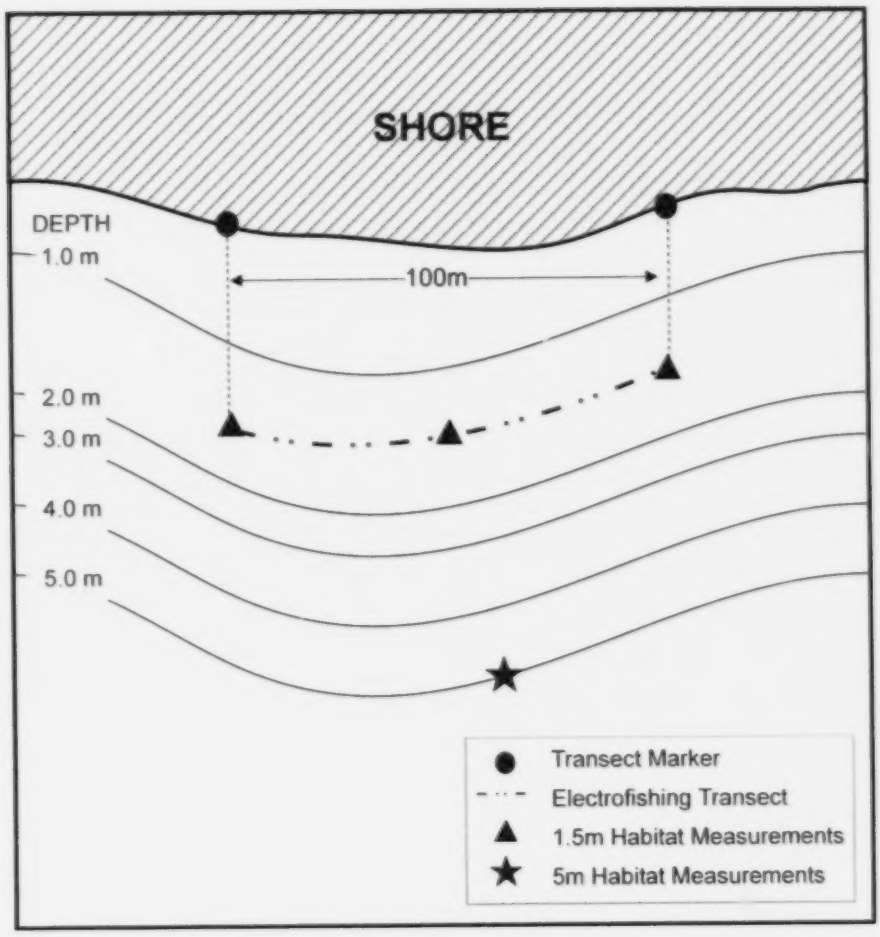

Figure 1: Figure showing the location of the electrofishing transects in relation to the shoreline and offshore bathymetry.

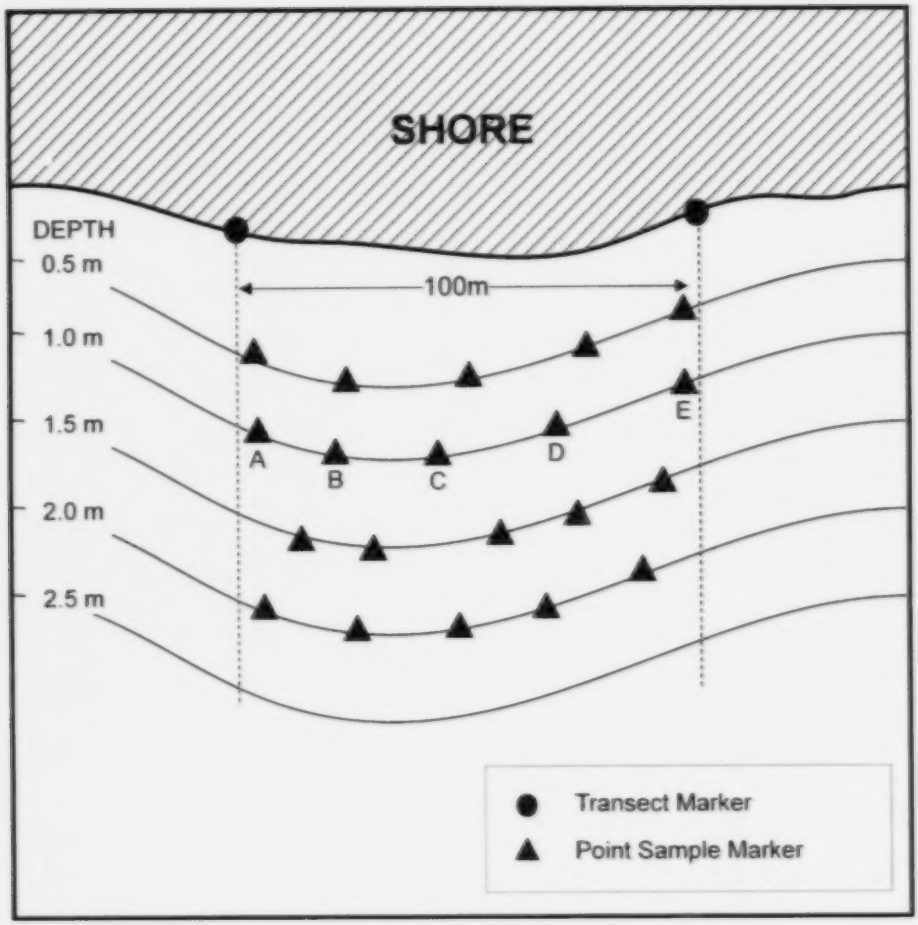

Figure 2: Figure showing the location of electrofishing point samples in relation to the shoreline.

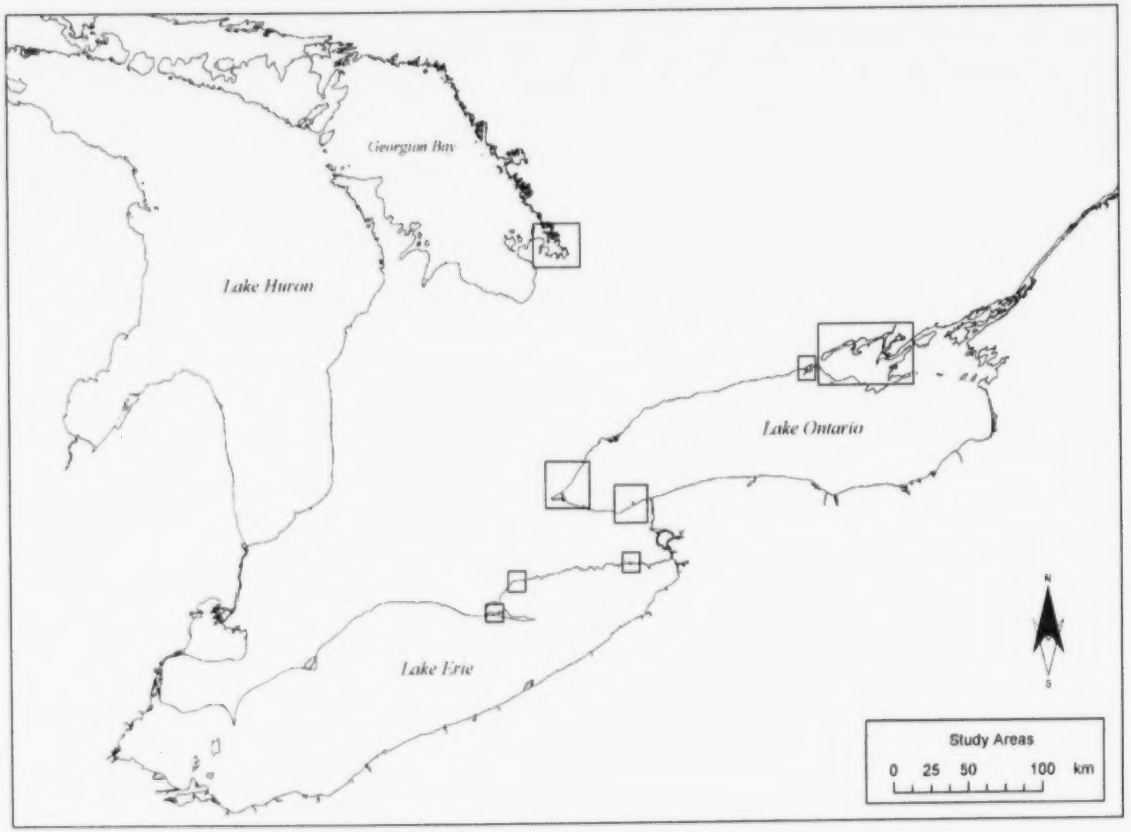

Figure 3: General location of all study areas.

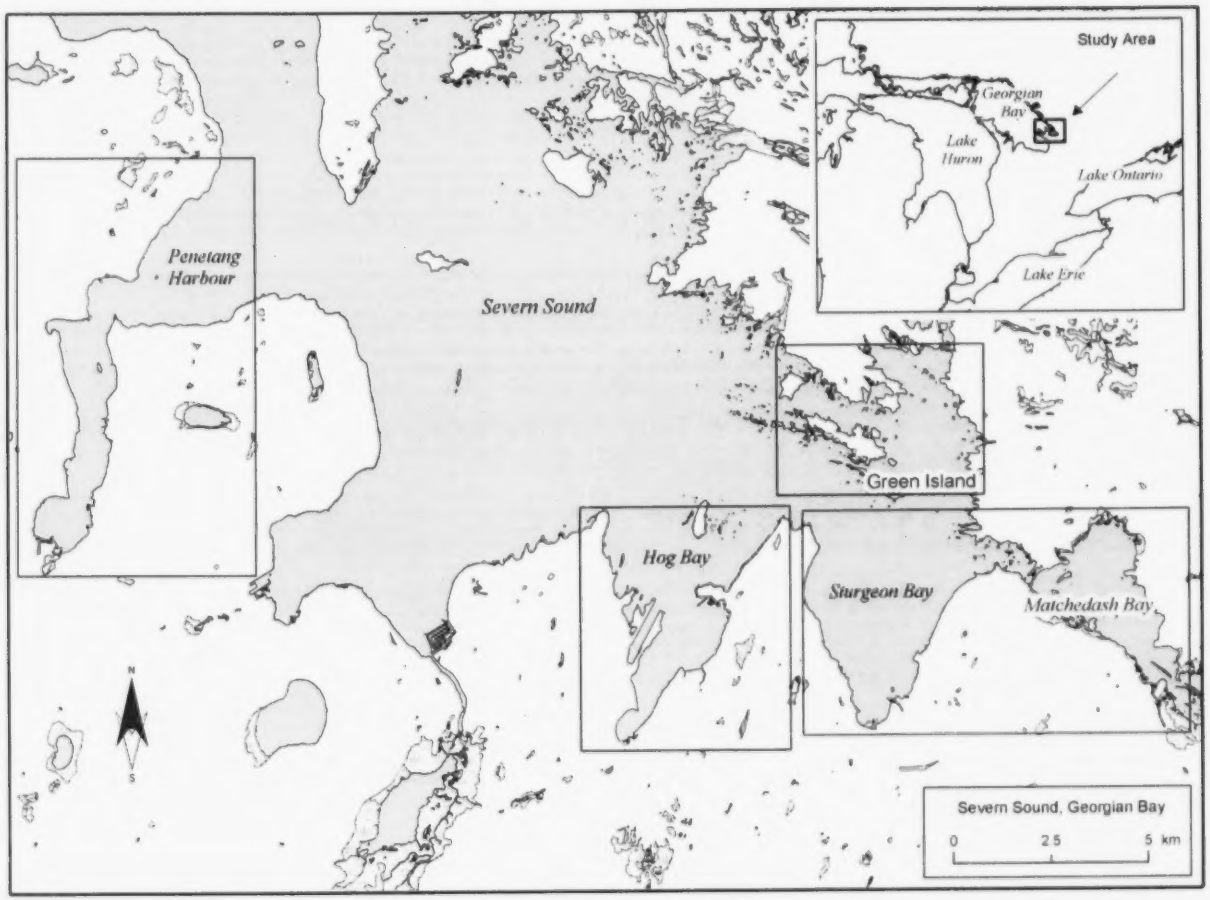

Figure 4: Overview of Severn Sound, Georgian Bay

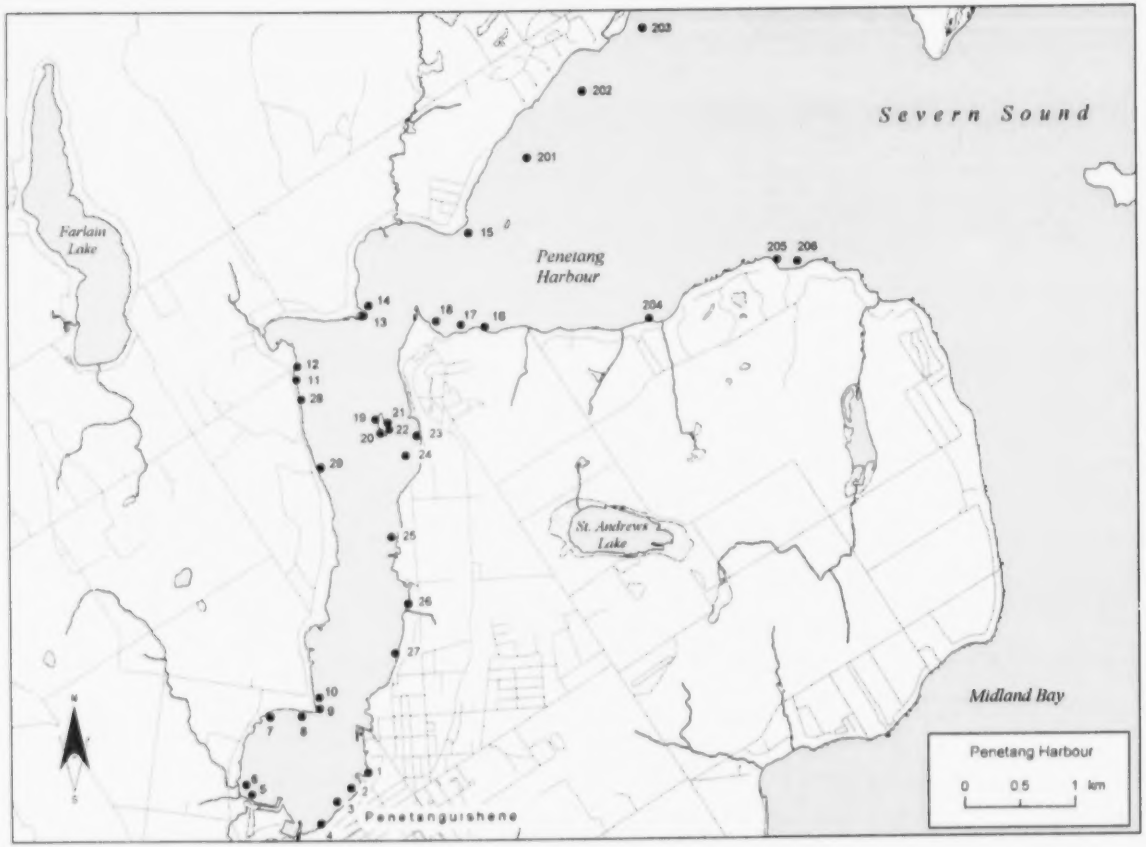

Figure 5: Penetang Harbour

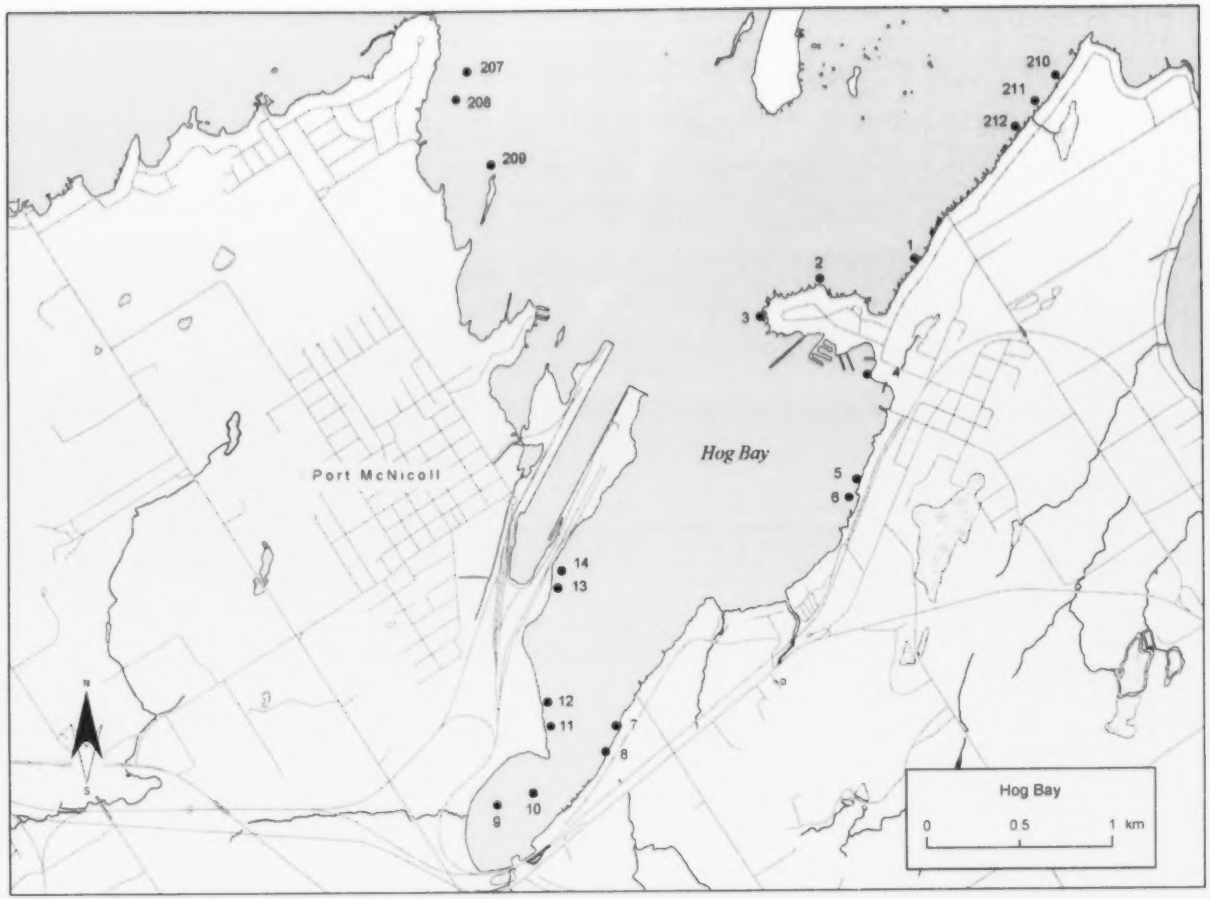

Figure 6: Hog Bay

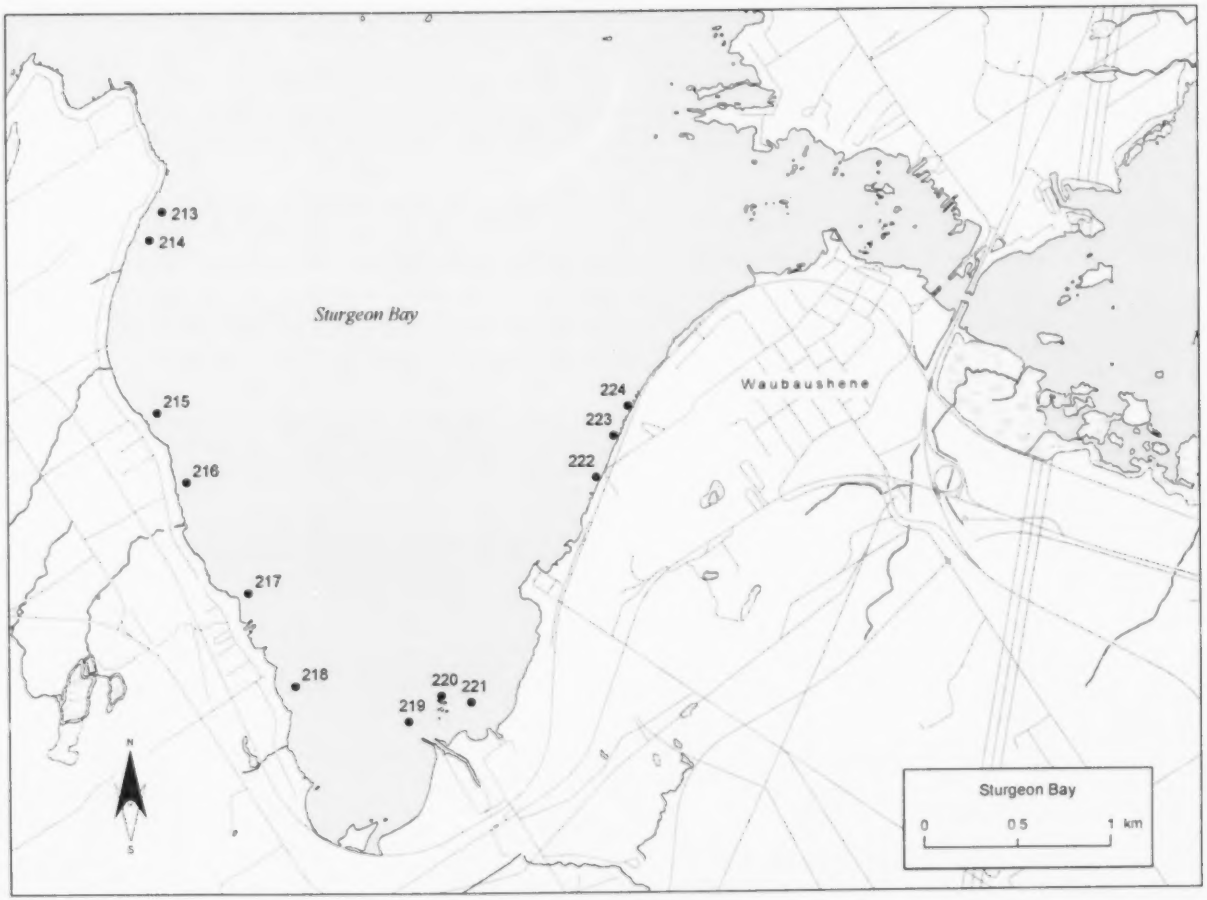

Figure 7: Sturgeon Bay

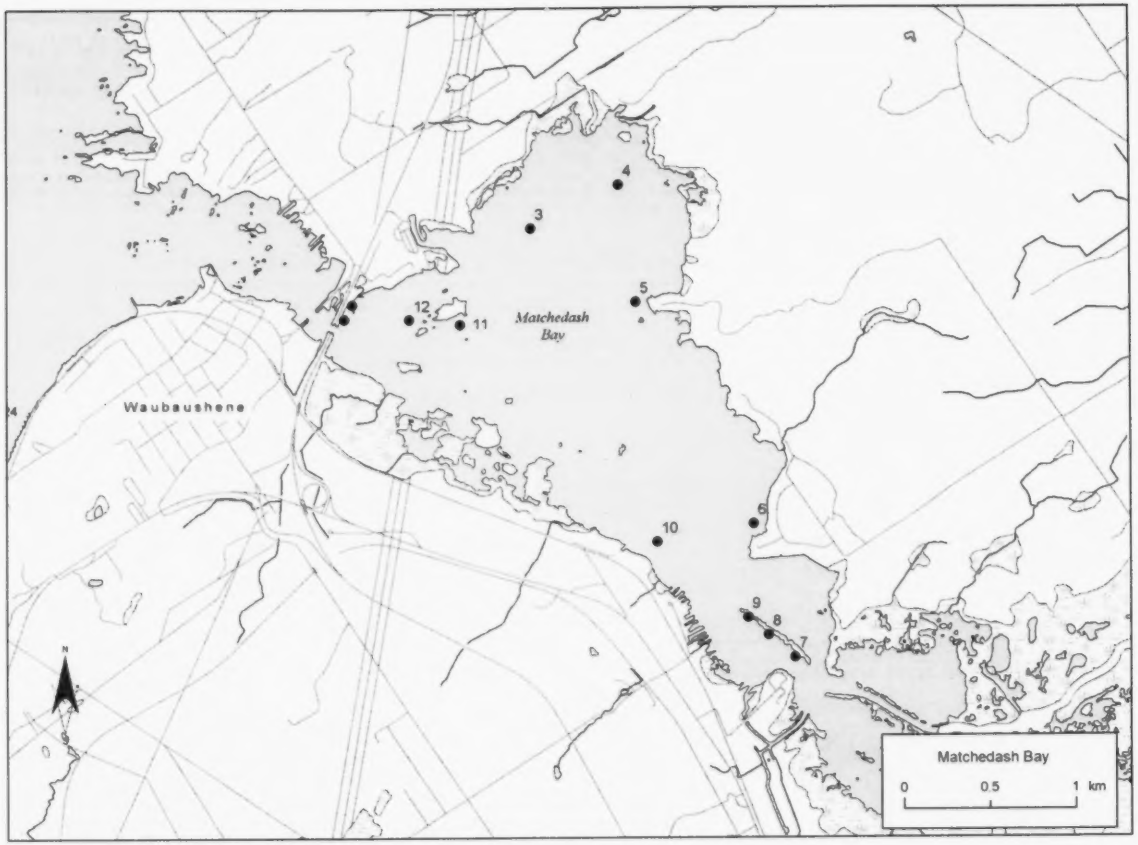

Figure 8: Matchedash Bay

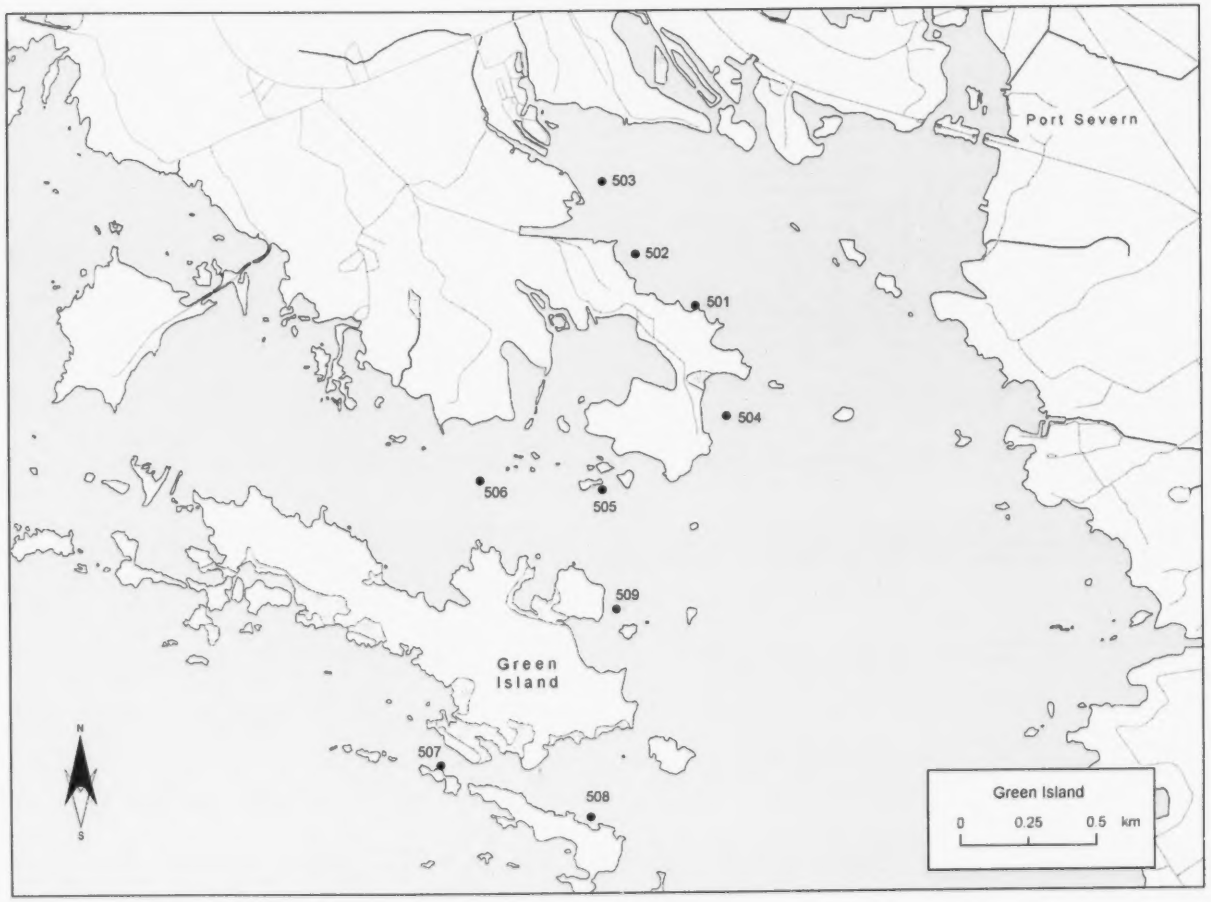

Figure 9: Green Island

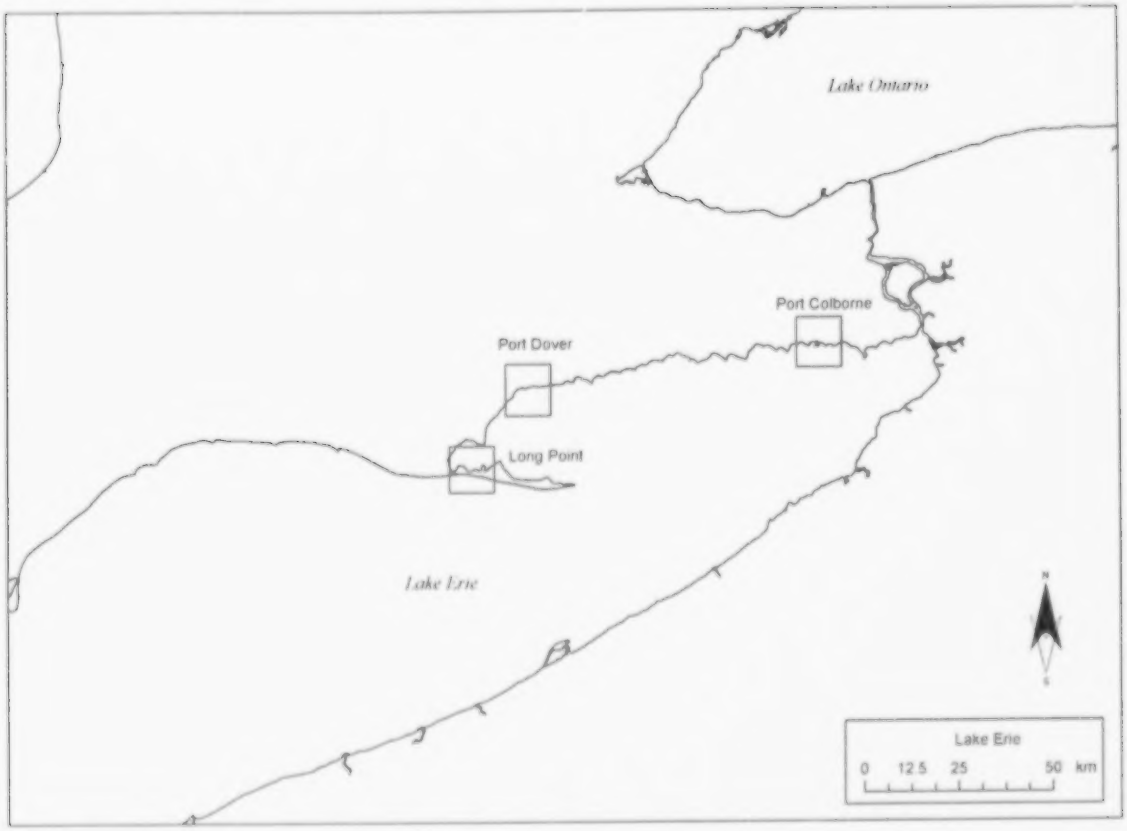

Figure 10. Overview of Lake Erie

Figure 11: Long Point

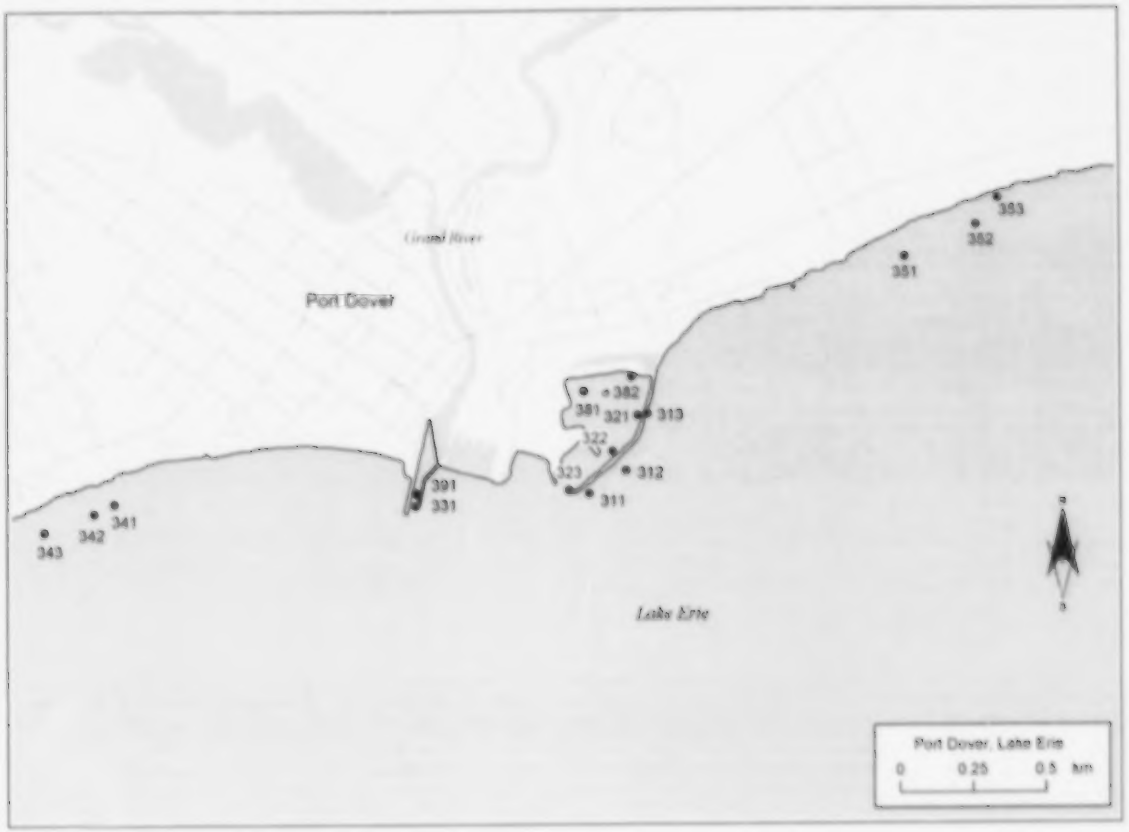

Figure 12: Port Dover

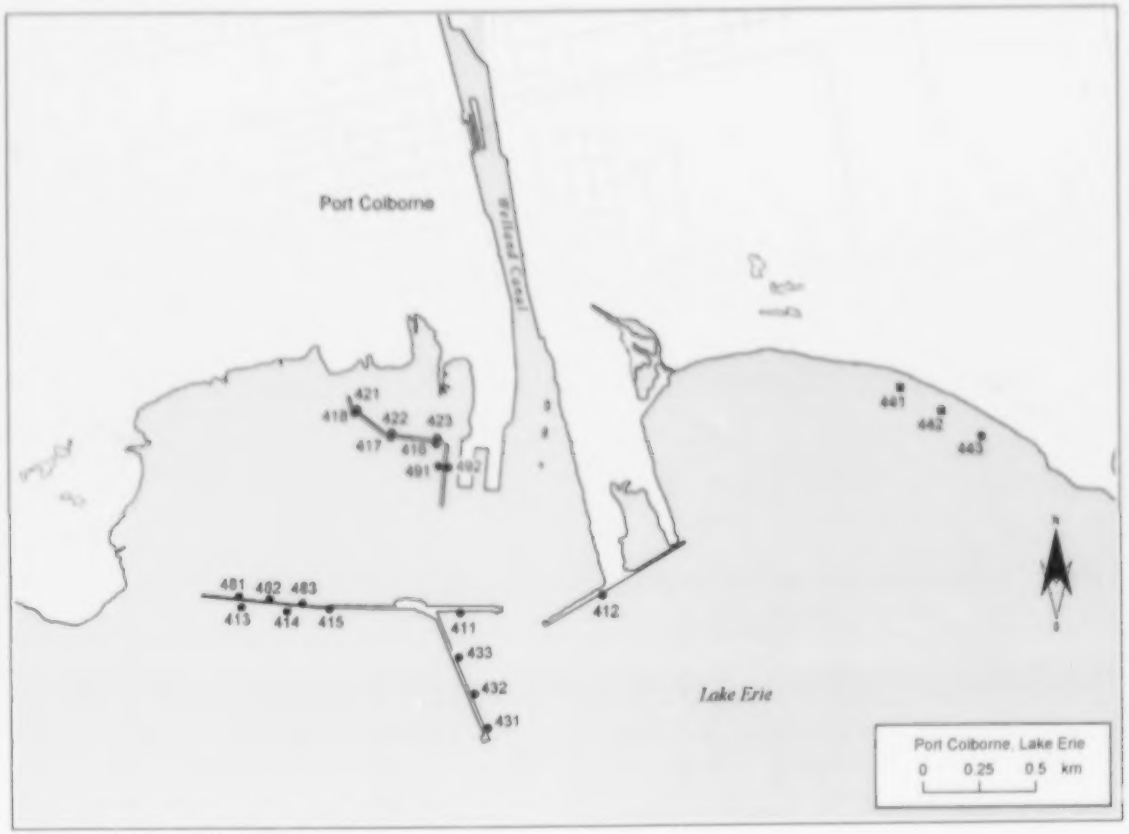

Figure 13: Port Colborne

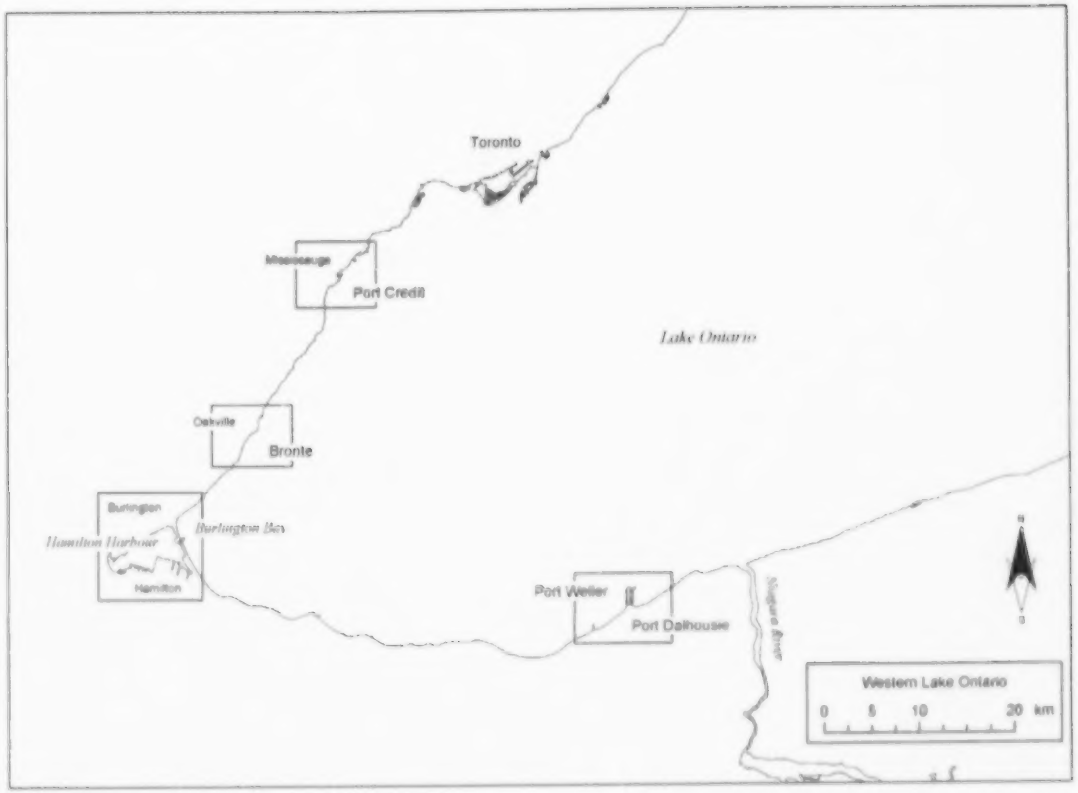

Figure 14: Overview of western Lake Ontario

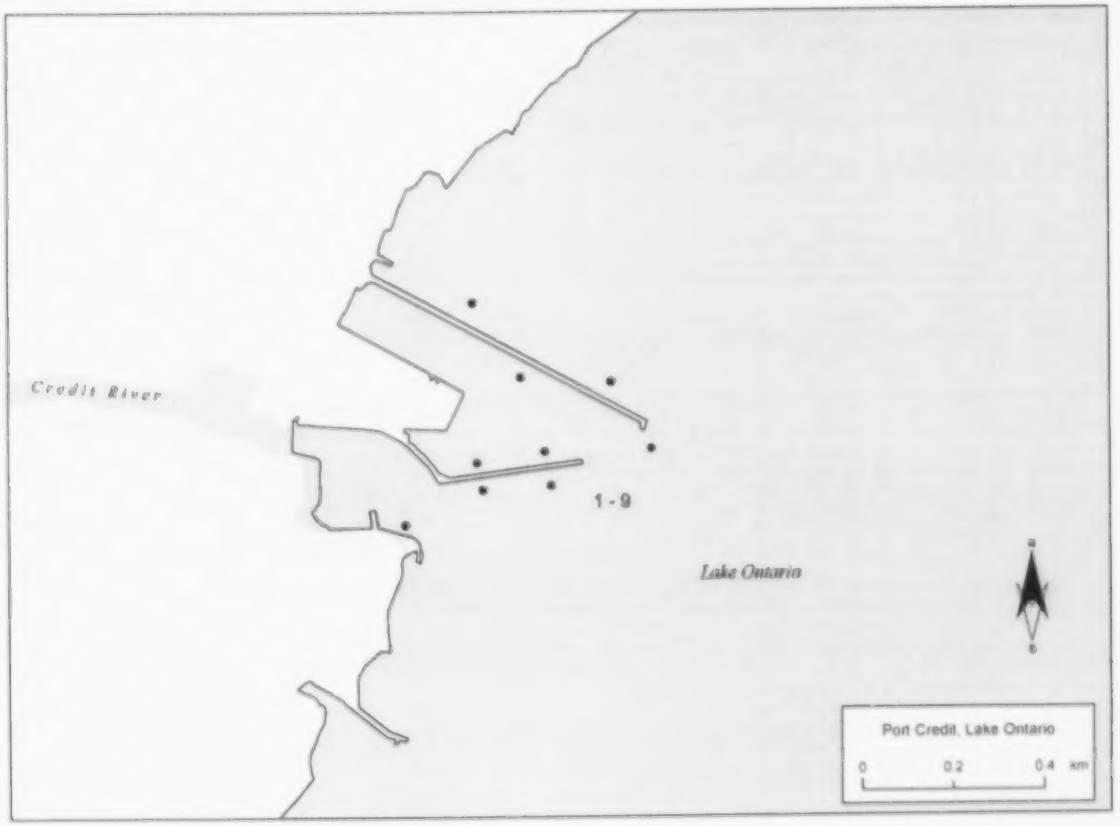

Figure 15: Port Credit

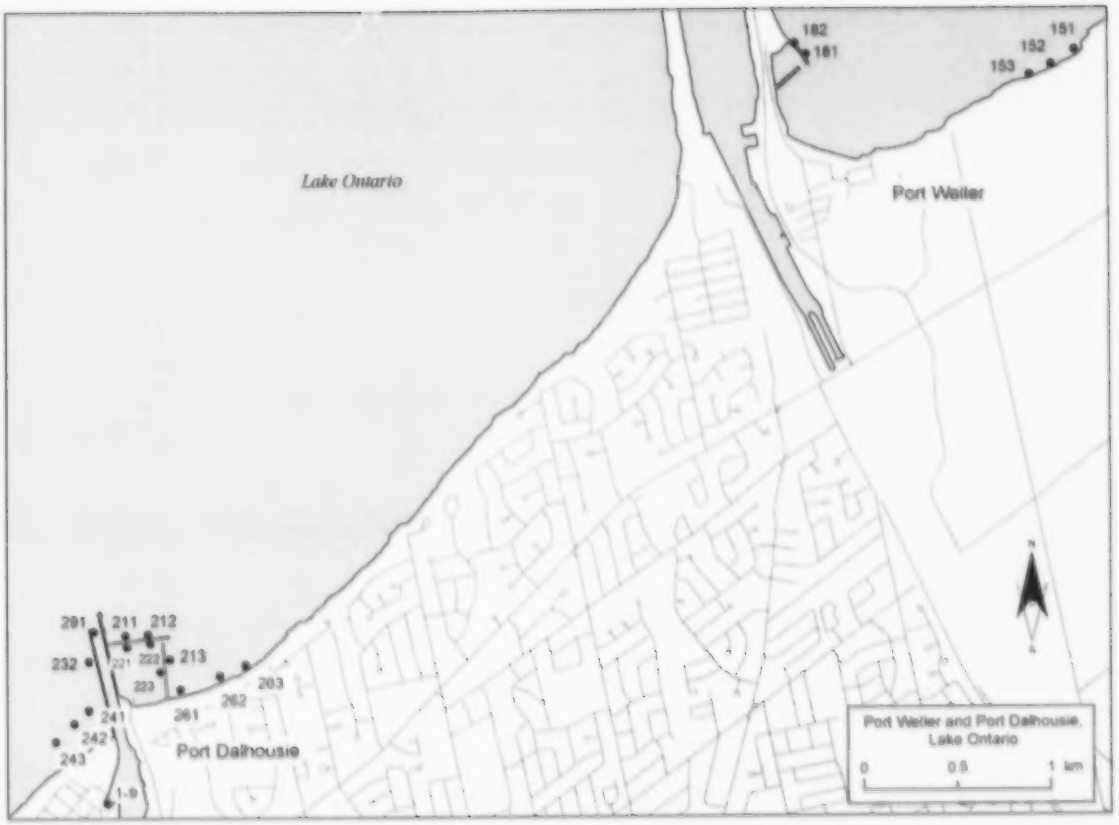

Figure 16: Port Weller and Port Dalhousie

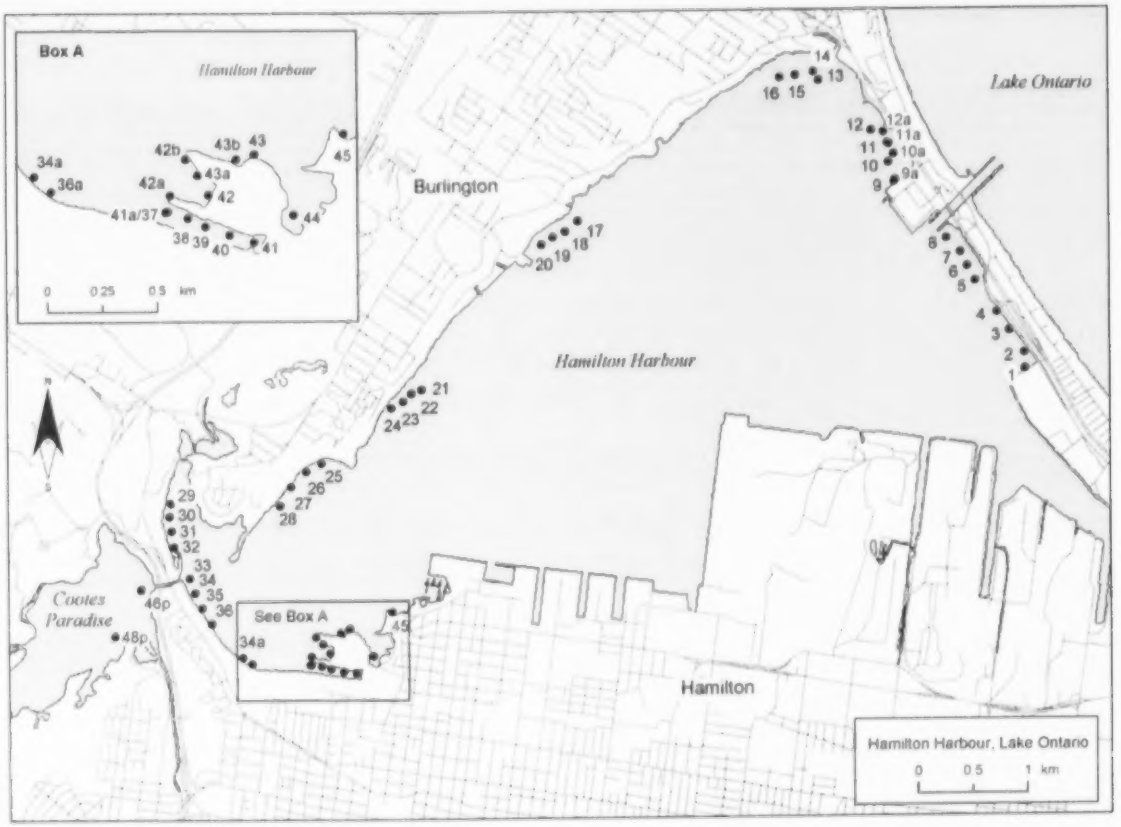

Figure 17: Hamilton Harbour

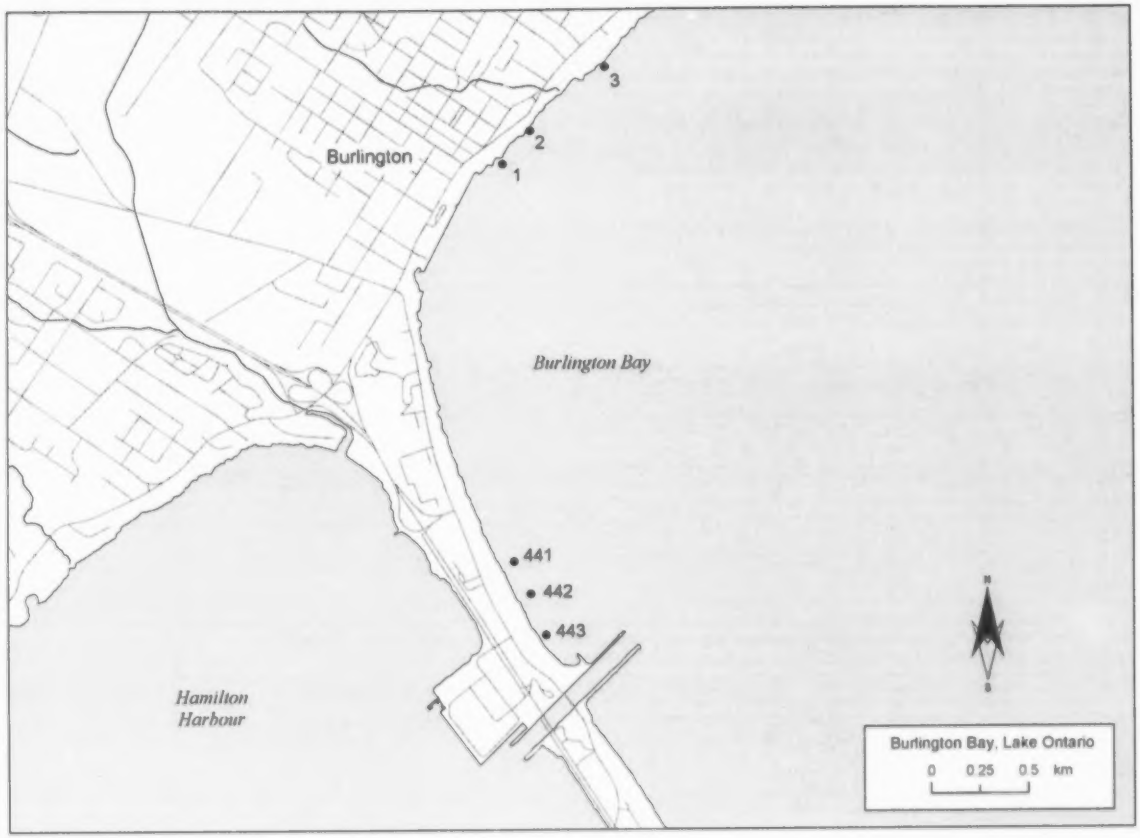

Figure 18: Burlington waterfront

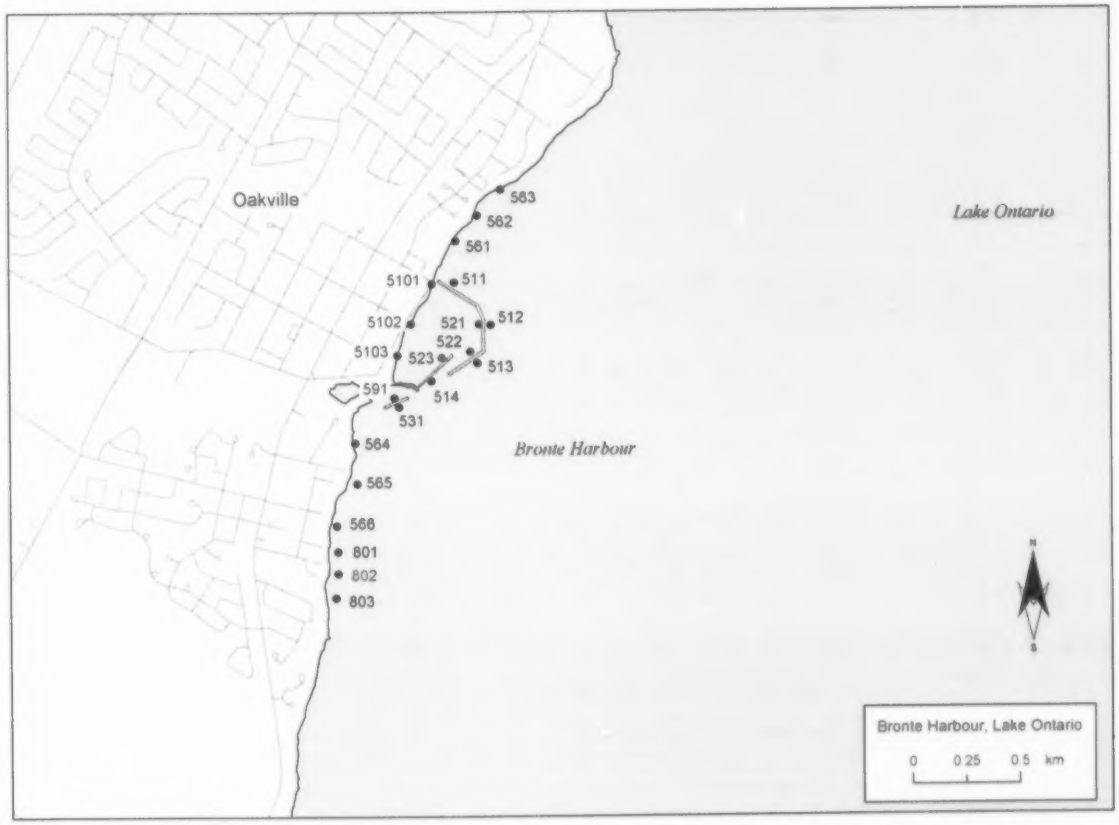

Figure 19: Bronte Harbour

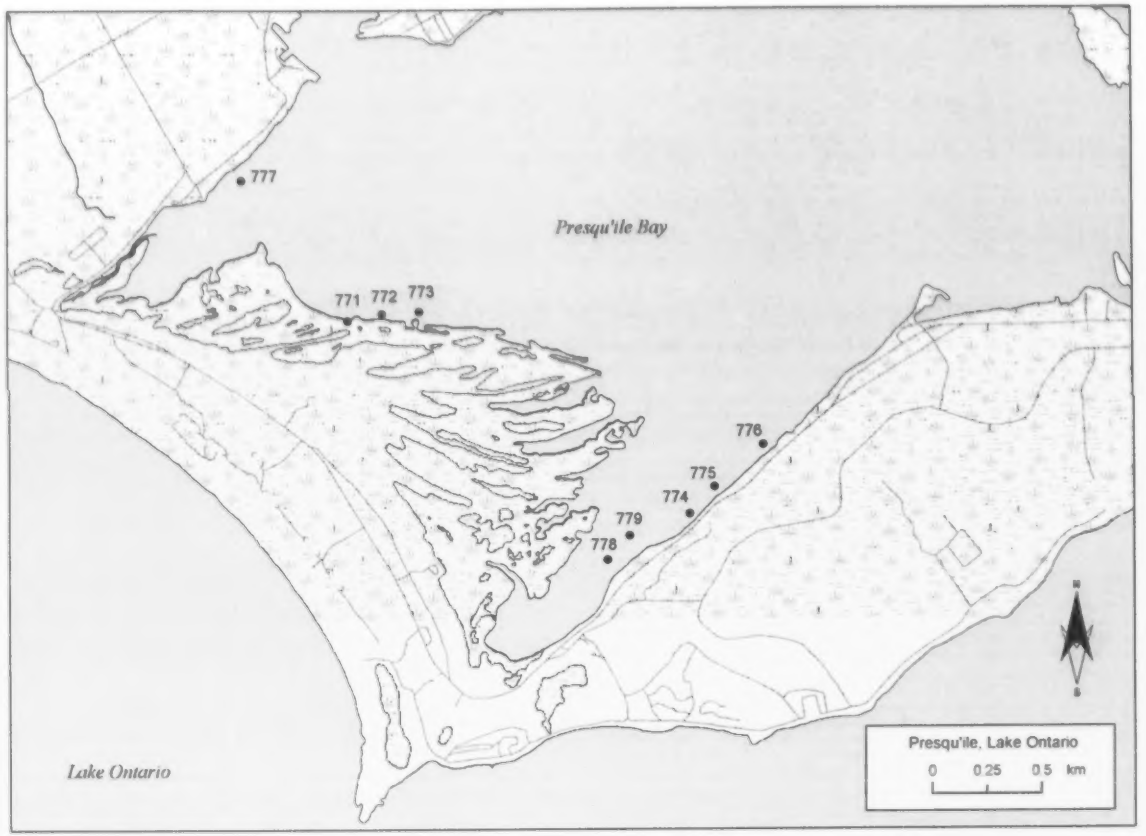

Figure 20: Presqu'ile Bay

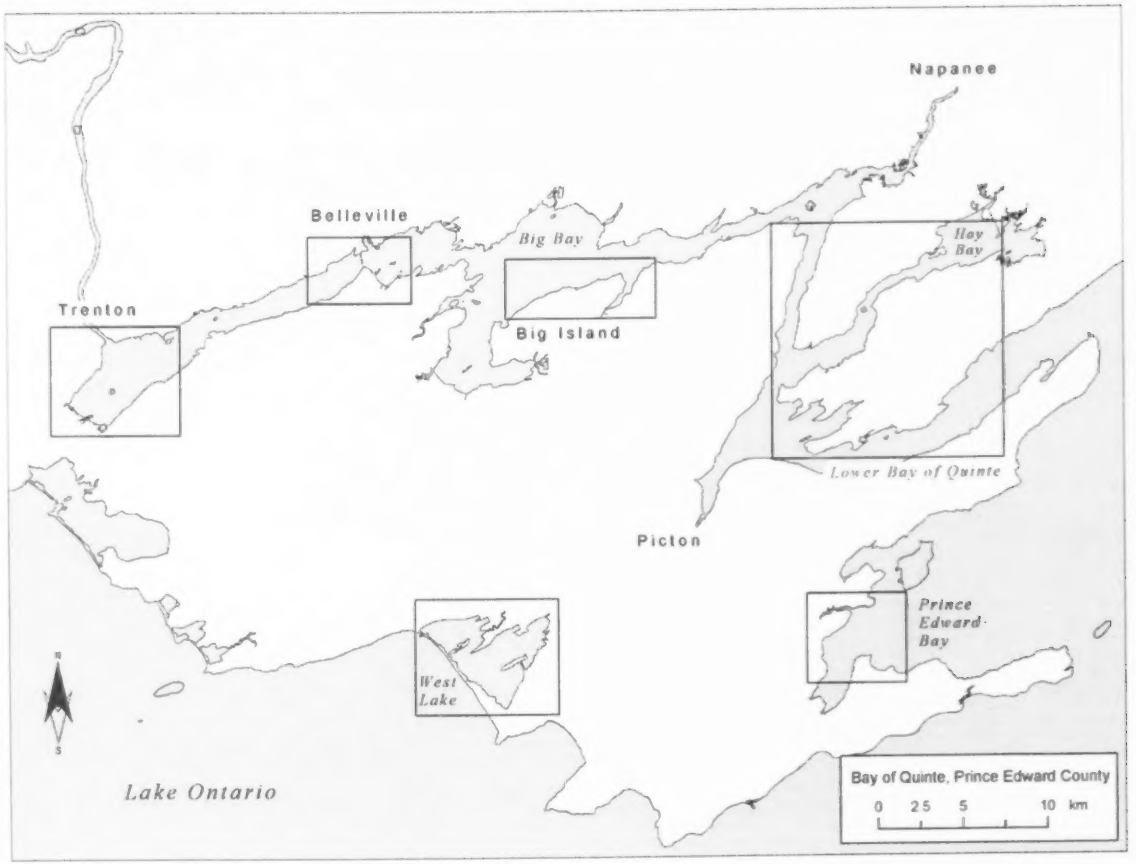

Figure 21: Overview of the Bay of Quinte and Prince Edward County sampling areas

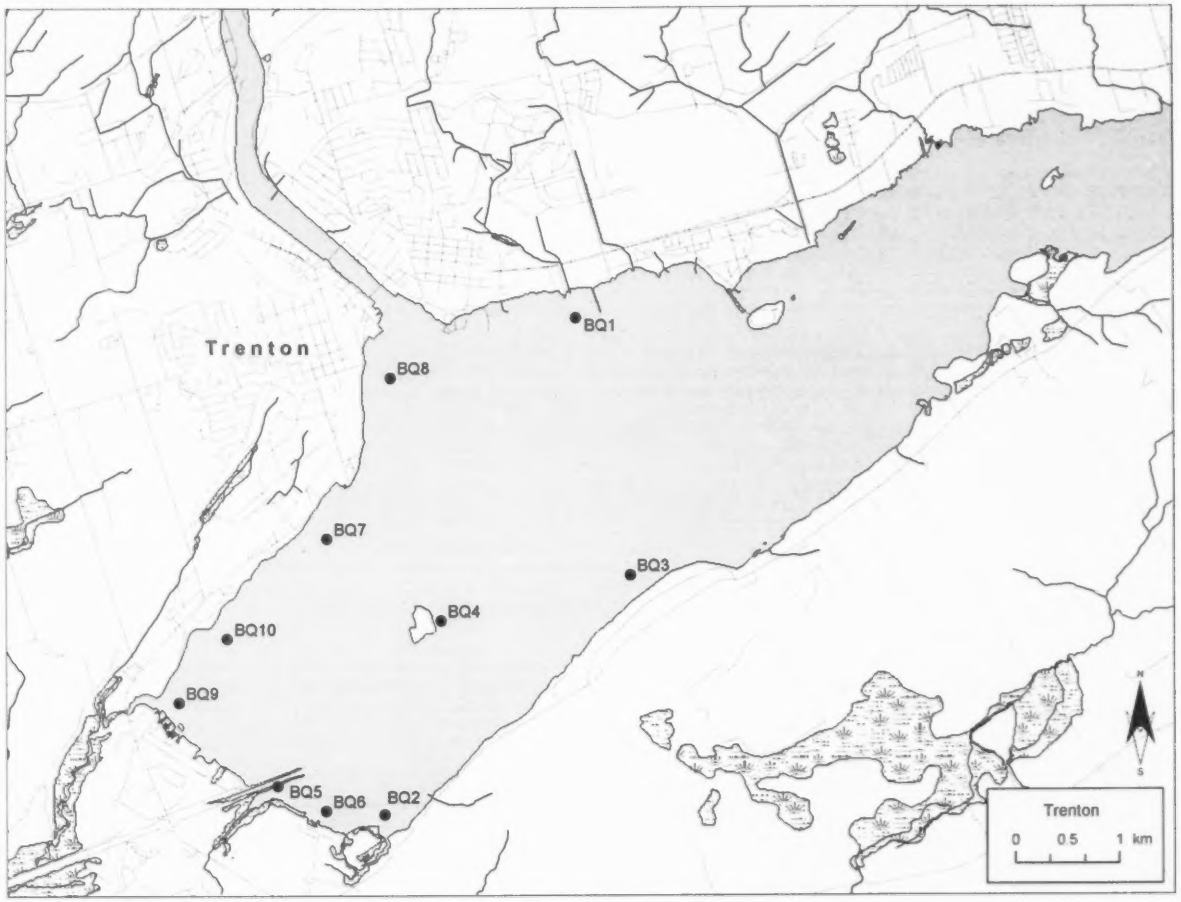

Figure 22: Trenton Harbour

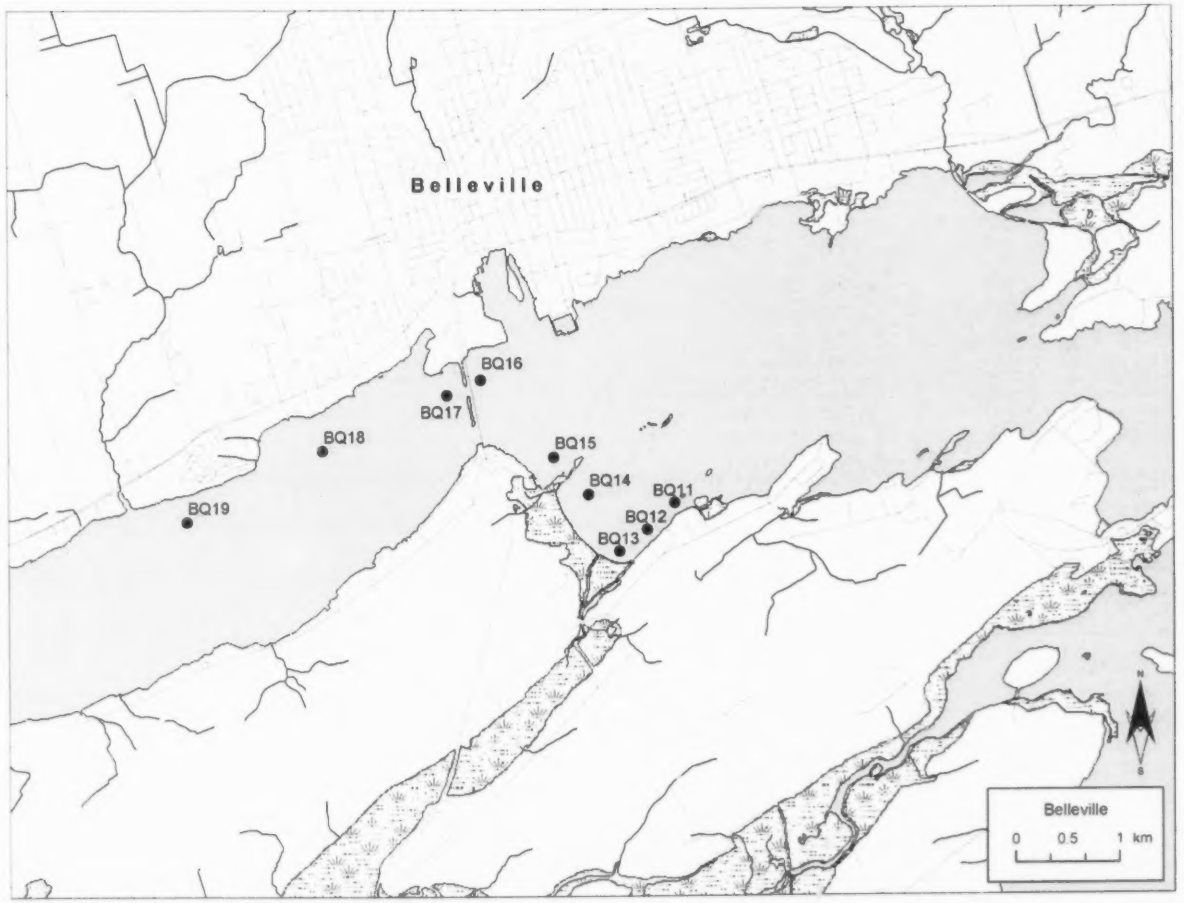

Figure 23: Belleville

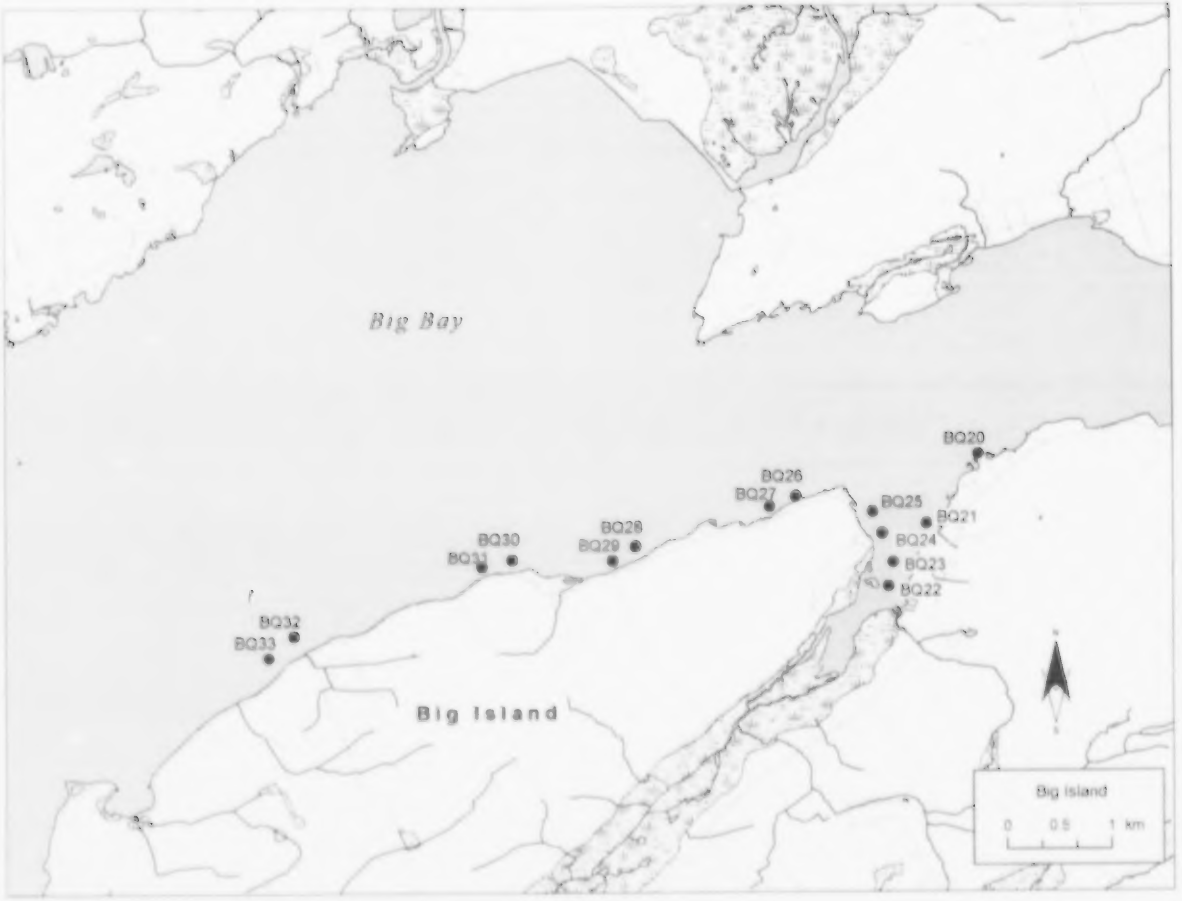

Figure 24 Big Island

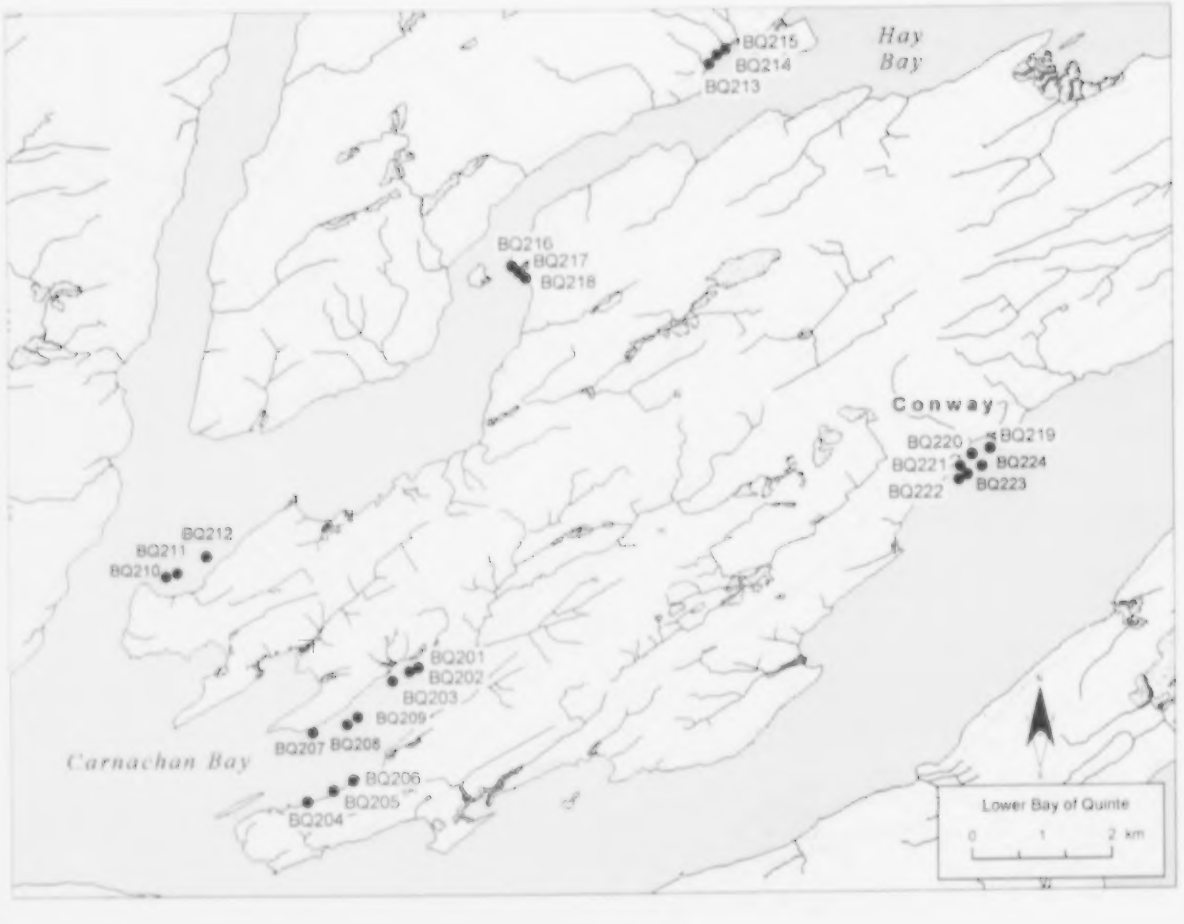

Figure 25: Lower Bay of Quinte

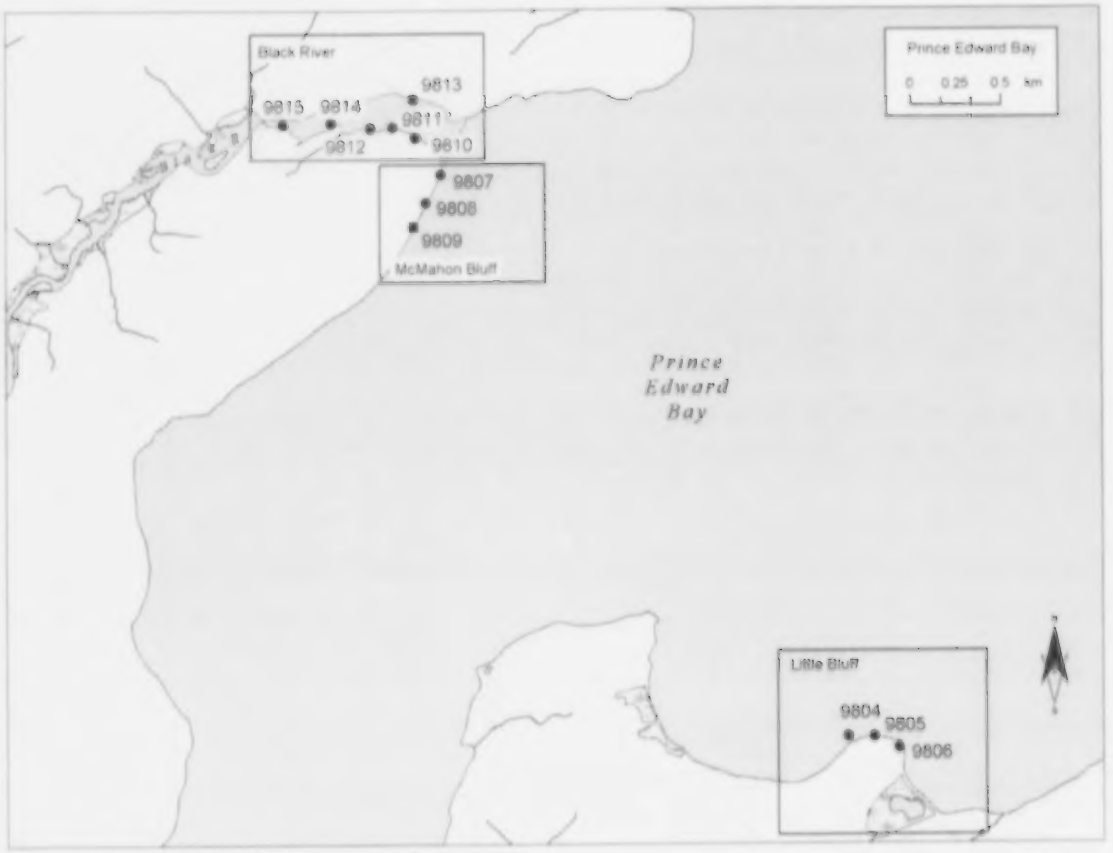

Figure 26 Prince Edward Bay

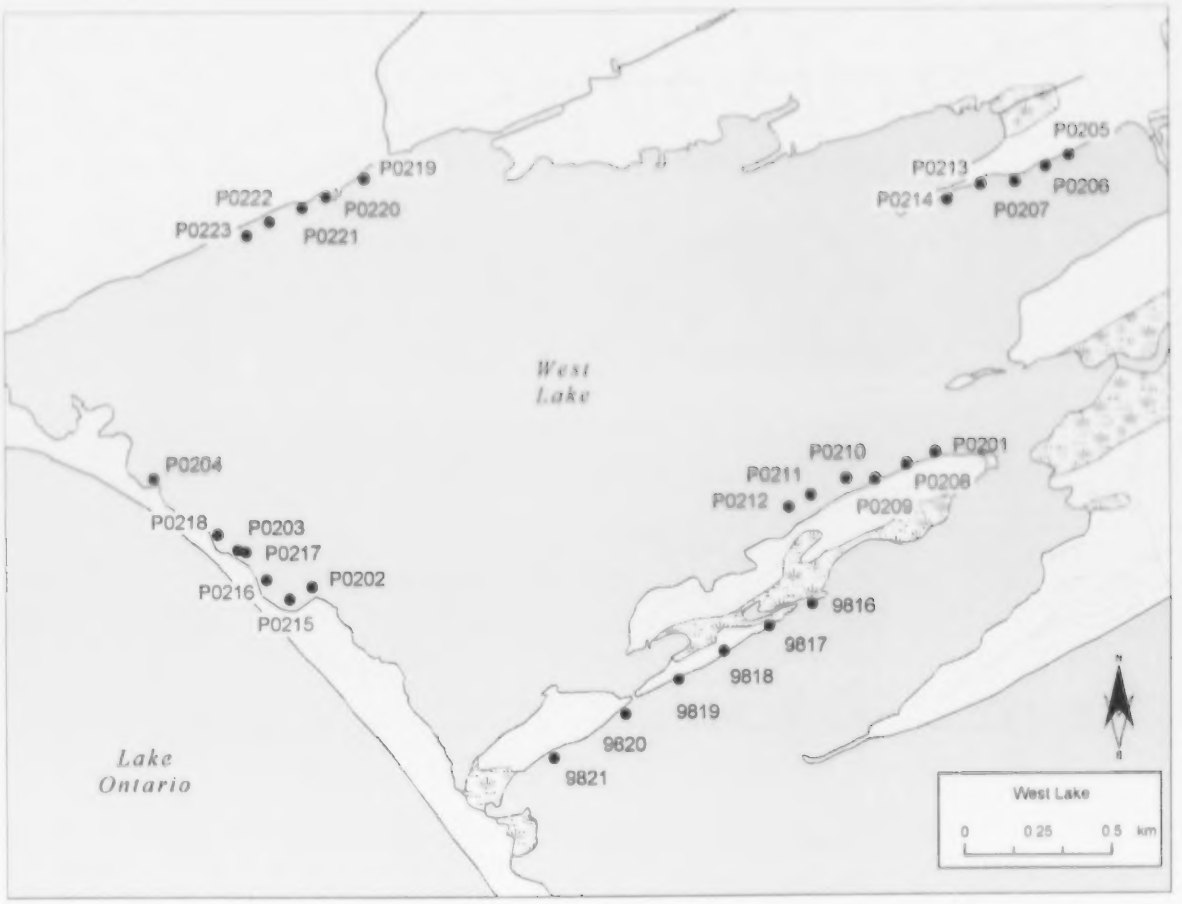

Figure 27: West Lake

Appendix 1. List and description of data fields for electrofishing fish field data sheet

Data Element	Description
Location	One geographic location or area within which sampling stations are located
Date	Date of electrofishing survey
Transect	Transect number (pertaining to line transect names)
Time Start	Time electrofishing survey began (24 hour clock)
Time Finish	Time electrofishing survey finished (24 hour clock)
Shocker Seconds	Duration of electrofishing time in seconds (read from the console)
Sheet_of_	Current sheet # and total sheets for electrofishing transect
Time Period	Time of electrofishing, check either before dusk or after dusk
Amps	Amps put out during electrofishing, (e.g. 8.0-8.2)
Volts	Voltage setting (always 340)
Percentage of Range	Percentage of output (read from the console)
Wind Speed (0-9)	A rating of wind speed on a scale of 0 to 9, in increments of 5kph (based on weather info)
Wind Direction	Direction of predominate wind (1=N, 2=E, 3=S, 4=W). NW would be recorded as 1.4 (based on weather info and field compass)
Id #	Consecutive numbering of fish, for data entry
SPP	Species name or code number from MNR species code list
FL (mm)	Fork length of fish measured in mm, total length for fish with a rounded or truncated caudal fin
Wt. (gm)	Total fish weight in grams
Sex	Sex of fish
Scale #	Scale sample number (if determined)
Note	Any extra information about fish (i.e. tumors, fin clips)
Batches	Number and weight of fish exceeding 20 fish per species
SPP	Species name or MNR code
Number of Fish	Number of fish in batch
Batch Weight (gm)	Total weight of batched fish
Notes	Any additional information or comments about electrofishing run (i.e. strong winds, excess vegetation, stalling motor)
Data Verification	The date and initials of person performing data entry and verification are entered in this area

Appendix 2. List and description for electrofishing line transect habitat field data sheet

Data Element	Description
Location	Geographic location or area within which sampling stations are located
Date	Date of habitat survey
Transect	Transect number
Time (24hr)	Time in 24 hr clock
Mid-Transect	Measurements taken at the midpoint between transect markers
Secchi Depth (m)	Depth secchi dish can be seen at mid transect
Temp (°C)	Water temperature in °C, at mid transect, taken at the surface, mid-depth(0.75m) and bottom (1.5m)
Conductivity (µS/cm)	Conductivity readings at mid transect, measured in µS/cm taken at surface, 0.75m and 1.5m, regulated to 25 °C
Dissolved oxygen (mg/L)	Dissolved oxygen readings in mg/L, measured at surface, 0.5m and 0.75m
5 m depth near transect	Measurements taken at 5m depth perpendicular to transect
5 m Secchi Depth (m)	Secchi depth reading at 5m depth contour
5 m Temp (°C)	Temperature in °C at surface, 2.5m and bottom (5.0m)
5 m Conductivity (µS/cm)	Conductivity reading taken in µS/cm at surface, 2.5m and 5.0m
5 m Dissolved oxygen (mg/L)	Dissolved oxygen taken at surface, 2.5m and 5.0m
Echogram Times (S, E)	Start and stop times of echogram, recorded as hh:mm:ss
Pulse width	Pulse width setting on echogram (default value 30)
Surface clutter	Surface clutter setting on echogram (default value 1)
Discrimination	Discrimination setting on echogram (default value 0)
Paper speed	Paper speed setting on echogram (default value 5)
Transect marker descriptions	Check appropriate box for accuracy of GPS readings

Appendix 2 continued

Data Element	Description
Latitude	Latitude of marker, recorded as dd mm.mmm (NAD 83)
Longitude	Longitude of marker recorded as dd mm.mmm (NAD 83)
Orientation of marker	Orientation of marker (i.e. is marker to the N, S, E or W)
Distance to shore	Distance to shore from marker (recorded in m)
Sediment categories	Check type and density of sediments observed
Marker description	Record any additional information about transect marker (i.e. changes in landmarks, reflectors added)
Waypoint name	Waypoint name given to marker for GPS purposes
Observer	Name of person observing macrophytes
Density	Check one box describing the density of macrophytes
Names of dominate types	Record the dominate types of vegetation found in the transect (using a key such as Newmaster, S.G., A.G. Harris, L.J. Kershaw. 1997. Wetland plants of Ontario. Lone Pine Publishing, Edmonton Alberta.)
Notes	Record any notes regarding the vegetation
Comments	Record any general comments about the transect habitat data
Data verification	The date and initials of person performing data entry and verification are entered in this area

Appendix 3. List and description for electrofishing point sample field data sheet

Data Element	Description
Location	Geographic location or area within which sampling stations are located
Date	Date of electrofishing survey
Transect	Transect number (pertaining to line transect names)
Point	Name of point (depth and label, i.e. 1.0a, 1.5b, as indicated on float marker)
Depth (m)	Depth of point sample
Time (24hr)	Time of habitat observations (24 hr clock)
Distance to shore (m)	Distance from float marker to shore
Latitude	Latitude of point recorded in dd mm.mmm
Longitude	Longitude of point recorded in dd mm.mmm
Sediment categories	Check type and density of sediments observed
Temperature (°C)	Water temperature at mid-depth of the point
Conductivity (µS/cm)	Conductivity readings at mid-depth of the point
Dissolved oxygen (mg/L)	Dissolved oxygen readings at mid depth of the point
Macrophyte density	Select density of macrophytes
Macrophyte composition	Select type and dominance of macrophytes
Data entry and verification	Enter date and name of person performing data entry and verification

Appendix 4. List of tasks and safety checklists to complete before initiating an electrofishing boat survey.

Tasks	Checklist	Annual	Daily
Equipment and safety checks			
	Boat		
	Check hull integrity	✓	✓
	Check to confirm that painted areas are intact and the proper colour.	✓	✓
	Check to confirm that safety railing is intact and sturdy.	✓	✓
	Check flooring to confirm that it is non-skid and secure	✓	✓
	Check that all metal equipment in the boat is electrically bonded /connected to the hull with a volt/ohm metre	✓	✓
	Check to confirm that all batteries are properly enclosed and vented.	✓	✓
	Check to confirm that fuel containers are up to regulation standard	✓	
	Check to confirm that boat is cleaned and all equipment is stored in compartments	✓	✓
	Confirm that all decals, numbers, and names are intact and legible	✓	
	Check that navigational lights, head lights, back-up lights, deck lights, dash lights and overhead lights are working.	✓	✓
	Check that fuel lines are in good condition	✓	
	Check to ensure that a tool kit is complete and present	✓	
	Check to ensure that miscellaneous equipment (i.e., fuses, spare boat plug) is onboard and intact	✓	
	Check to confirm that the boat plug is present and that the livewell is functioning and standpipe is present	✓	✓
	Check for adequate mechanical protection on wiring	✓	
	Check for adequate connectors and interlocking.	✓	
	Safety Equipment		
	Check to ensure that the following safety equipment is on board: two wooden paddles, six approved distress flares, first aid kit, one class B-I fire extinguisher working and present, life jackets for maximum number of crew, bullhorn present and working, anchor and rope present(min. 15.24 m), one bailer or manual pump, safety ladder, and approved buoyant heaving line	✓	✓
	Check to ensure that the manuals "Smith-Root, Inc. Electrofishing Boat Owners Manual" and "Smith-Root, Inc., GPP Generator Manual" are onboard and kept in a waterproof bag on the boat.	✓	✓
	Outboard Engines		
	Check to ensure that the main and auxiliary engines are working and servicing is up to date	✓	
	Check to ensure no gasoline or oil leaks	✓	
	Check to ensure that a propeller and spare are present and in working condition	✓	✓
	Check for adequate oil levels in reservoir		✓
	Check for adequate fuel		✓
	Check to ensure that the cooling water is coming out of the engine water pump indicator		✓
Equipment and safety checks, cont'd	**Trailer**		

Tasks	Checklist	Annual	Daily
	Check for frame integrity	✓	
	Check that tires are properly inflated and checked for visible damage or wear	✓	✓
	Check that wheel bearings are greased, spare tire, trailer hitch, safety chain and lock all functioning, lights working, winch working properly and in good condition, rollers all present and operating smoothly, tie down straps working and in good shape.	✓	✓
	Electrofisher		
	Check to ensure that all controls and gauges are operational	✓	✓
	Ensure that unit has been checked and overhauled by manufacturer in last 3 years (Smith-Root electrician)	✓	
	Check to ensure that audible tone generator is working	✓	✓
	Check to ensure that all foot switches are present and working	✓	✓
	Check to ensure that high Voltage flashing lights are working.	✓	✓
	Check to ensure that "Kill Switch" is working	✓	✓
	Check to ensure that primary booms are secure and isolated from high voltage	✓	
	Check to ensure that anode arrays are in good shape and free of oxidation	✓	
	Check to ensure that there is adequate mechanical protection of wiring	✓	
	Conduct high voltage checks		✓
	Generator		
	Ensure that generator is electrically bonded/connected to hull	✓	✓
	Ensure that exhaust is directed away from operator	✓	✓
	Ensure that all electrical connections are secure and protected	✓	✓
	Ensure that oil is changed and engine servicing is up to date	✓	✓
	Ensure that mountings are secure	✓	
	Check to ensure the gas is full		✓
	Other equipment		
	Ensure net handles are made of non-conductive material (e.g., wood)		✓
	Ensure that each crew member is wearing waterproof, insulated work gloves		✓
	Ensure that gloves are dry inside		✓
	Ensure that each crew member is wearing insulated rubber boots		✓
	Ensure that each crew member is briefed on boat operations and safety procedures		✓
	Ensure that each crew member is wearing protective hearing gear (where applicable -see below)		✓
	Ensure that each crew member has a foot activated "kill switch"		✓
	Ensure that each crew member is aware of emergency procedures (e.g., hospital route, phone numbers, etc.)		✓
	Ensure that the weather forecast has been checked		✓
	Inform local authorities of your location and work schedule (Activate Sail Plan)		✓
Train all personnel			
	All crew members and crew leader must have CPR and First Aid.	✓	
	All crew leaders must be certified through the Ontario Ministry of Natural Resources (OMNR) Electrofishing certification	✓	

Tasks	Checklist	Annual	Daily
Train all personnel cont'd	program.		
	All crew members must be certified through either the OMNR certification program or through the crew leader	✓	
	All crew leaders and members must read "Electrofishing Guidelines and Procedures" (Goodchild 1986)	✓	
	All boat operators must have a medical examination once each year.	✓	
	The crew leader must read and understand the contents of the "Smith-Root, Inc. Electrofishing Boat Owners Manual" and "Smith-Root, Inc., GPP Generator Manual". Copies should be kept in a waterproof bag on the boat.	✓	
	All crew members must sign a contract stating that they have received the proper training (above) and read all the required materials.	✓	
Plan the trip			
	No electrofishing will be conducted under heavy rain conditions or in the presence of lightning. Postpone the trip until weather conditions have improved.		✓
	Staff will be trained in accordance with recommended measures listed under "Train all personnel".		✓
	Required safety equipment is available as listed in Safety Equipment- .See above.		✓
	Activate Sail Plan before and after electrofishing work		✓
Operations			
	Make sure that the aisles and steps on boat are free from clutter		✓
	Boat and live-well operators will wear protective hearing gear (e.g., earplugs)		✓
	All crew members must be wearing insulated rubber gloves and boots		✓
	If a large fish is captured, the netter should step off the foot pedal and walk the fish back to the live-well		✓
	The crew leader will ensure will occur at a safe distance from areas where people are working or recreating near or in the water.		✓
Small boat operations			
	Boat operators and crew must possess and carry Small Boat Operator Card.		✓
	Crew must carry Scientific Collectors Permit		✓

Appendix 5. Listing of sampled stations and associated habitat information. Habitat information from stations sampled between 1999 and 2002 was collected from the year of the last fish survey and habitat information from sites sampled prior to 1999 contain information from the productive capacity database for substrates sampled between 1991 and 1995 and macrophyte surveys between 1990 and 1995.

LOCATION	Station_ID	Location	Waterbody	Transect Location	Last Fish Survey	Dominant Substrate[1]	Macrophyte Density[2,3,4]
PENE	PH1	Penetang Bay	Severn Sound	Shore, AOC	2002	Si, Org	3
PENE	PH2	Penetang Bay	Severn Sound	Shore, AOC	1990	Si, Org	3
PENE	PH3	Penetang Bay	Severn Sound	Shore, AOC	1990	Si	3
PENE	PH4	Penetang Bay	Severn Sound	Shore, AOC	2002	Si	3
PENE	PH5	Penetang Bay	Severn Sound	Shore, AOC	1990	Si	3
PENE	PH6	Penetang Bay	Severn Sound	Shore, AOC	1990		3
PENE	PH7	Penetang Bay	Severn Sound	Shore, AOC	2002	Si, Org	2
PENE	PH8	Penetang Bay	Severn Sound	Shore, AOC	2002	Sa, Si, Org	2
PENE	PH9	Penetang Bay	Severn Sound	Shore, AOC	1990	Si	2
PENE	PH10	Penetang Bay	Severn Sound	Shore, AOC	1990	Si	3
PENE	PH11	Penetang Bay	Severn Sound	Shore, AOC	1990	Sa	1
PENE	PH12	Penetang Bay	Severn Sound	Shore, AOC	1990	Sa	1
PENE	PH13	Penetang Bay	Severn Sound	Shore, AOC	2002	Sa	2
PENE	PH14	Penetang Bay	Severn Sound	Shore, AOC	2002	Sa	2
PENE	PH15	Penetang Bay	Severn Sound	Shore, AOC	2002	Sa	1
PENE	PH16	Penetang Bay	Severn Sound	Shore, AOC	2002	Sa	1
PENE	PH17	Penetang Bay	Severn Sound	Shore, AOC	1990	Sa	2
PENE	PH18	Penetang Bay	Severn Sound	Shore, AOC	2002	Sa	1
PENE	PH19	Penetang Bay	Severn Sound	Shore, AOC	1990	Sa	3
PENE	PH20	Penetang Bay	Severn Sound	Shore, AOC	2002	Sa	2
PENE	PH21	Penetang Bay	Severn Sound	Shore, AOC	2002	Sa, Si	2
PENE	PH22	Penetang Bay	Severn Sound	Shore, AOC	1990	Sa	2
PENE	PH23	Penetang Bay	Severn Sound	Shore, AOC	2002	Sa, Si	3
PENE	PH24	Penetang Bay	Severn Sound	Shore, AOC	1990	Sa	3
PENE	PH25	Penetang Bay	Severn Sound	Shore, AOC	1990	Sa	2
PENE	PH26	Penetang Bay	Severn Sound	Shore, AOC	2002	Co, Sa	2
PENE	PH27	Penetang Bay	Severn Sound	Shore, AOC	1990	Sa	3
PENE	PH28	Penetang Bay	Severn Sound	Shore, AOC	1990	Sa	2
PENE	PH29	Penetang Bay	Severn Sound	Shore, AOC	2002	Sa, Si	2